ENGINEERING NEWS

A JOURNAL OF CIVIL, MECHANICAL, MINING AND ELECTRICAL ENGINEERING

Vol. LII. No. 13. New York, September 29, 1904.

TABLE OF CONTENTS

LEADING ARTICLES: Page

The Puyallup River Water-Power Development near Tacoma, Wash. (illustrated)... 271
The Cable Incline of the Puget Sound Power Co..... 279
The Passenger Car Ventilation System of the Pennsylvania R. R. (illustrated)..... 280
The International Electrical Congress..... 280
Three-Hinged Steel Arch Trusses for the U. S. Government Building; St. Louis Exhibition (illustrated)..... 282
Utilization of Exhaust Steam in Low Pressure Steam Turbines; Leonce Battu..... 282
Copper Sulphate Treatment of Lakes Clifton and Montebello, Baltimore Water-Works; Alfred M. Quick..... 283
Through the Lake Superior Iron and Copper Mines with the American Institute of Mining Engineers.—I..... 285
A Drill Hole Reamer (illustrated)..... 286
Coal Testing Plant at the St. Louis Exhibition..... 286
The Behrend Steel Sheet Piling (illustrated)..... 286

Page

Rearrangement of Tracks and Station Facilities at the Union Station, St. Louis, Mo. (illustrated)..... 290
EDITORIAL COMMENT: The Melrose Dynamite Disaster.—Utilizing Exhaust Steam in Steam Turbines.—More Experience with Copper Sulphate in Reducing Algae.—The Papers before the New England Water-Works Association..... 287
EDITORIALS: Some Specifications for Cast Iron Pipe..... 287
Comments on Specifications for Protecting Embankment Slopes..... 288
LETTERS TO THE EDITOR: A Table for the Computation of Sinking Funds; John Jerome Deery.—Economy in Coal Handling; H. S. K.—Measuring Deflections in Floor Tests (illustrated); Chas. H. Miller, M. Am. Soc. C. E.—A Device for Adjusting a Plumb-Bob String (illustrated); E. L. Colburn.—High or Low Elastic Limit Steel for Reinforcing Concrete; L. J. Mensch.—Good Brick Masonry laid with Lime-Cement Mortar (illustrated); H. K. Higgins.—Notes and Queries..288-289
ENGINEERING NEWS OF THE WEEK..... 294

THE PUYALLUP RIVER WATER POWER DEVELOPMENT NEAR TACOMA, WASHINGTON.

The cities of Seattle and Tacoma, Washington, and their suburban towns have in five years increased in population from 130,000 to upwards of 225,000. The growth of their manufacturing industries and construction of street and interurban electric railways has kept pace with the increase of population, and to supply the consequent demand for electric power, an unusually large generating plant of the most modern type has been constructed on the Puyallup River.

GENERAL PLAN OF DEVELOPMENT.—The Puget Sound Power Co., the owners of the plant, was organized in the year 1902, for the purpose of developing water power for use by the Stone & Webster properties in Seattle and Tacoma. Before beginning the construction of the plant, a careful investigation was made of the variations in the flow of the several rivers in western Washington and the other features which would affect the reliability of the service obtainable from each. A general plan was then adopted for the development of this power on the Puyallup River with an initial installation of 20,000 HP., the plans being made and the greater portion of the work carried out on the basis of continuing the initial installation to an ultimate development of 40,000 HP.

The design consists in diverting the Puyallup River just below the junction with the Mowich and carrying the same by means of a flume ten miles to a reservoir located on a high plateau and thence discharging by means of steel pipes against water-wheels in the power house under a head of 872 ft. The water-wheels so driven are to be direct connected to electric generators and the electric power so produced to be transmitted at a pressure of 55,000 volts, 48 miles to Seattle and 32 miles to Tacoma.

All water rights and the necessary land abutting on the river from the point of diversion to the point of return were secured, also all land necessary for flume and other structures, and the actual work of development was commenced March 1, 1903. To facilitate construction, a spur track 2½ miles long was built from the Kapowsin Station of the Tacoma Eastern R. R. to a new station at Electron, and continued a mile further to the power house site. From Electron a standard gage cable incline railway was built to hoist carr to an elevation of about 950 ft. to the reservoir site above the power house, and a wagon road was also built to the head works.

The first generator unit of 5,000 HP. was put into commercial operation delivering power to Seattle and Tacoma on April 14, 1904, less than fourteen months after work was commenced. The plant was put into complete operation for its initial installation of 20,000 HP. on July 23, 1904.

SOURCE OF SUPPLY.—The Puyallup River has its source in the glaciers of Mount Rainier, the highest mountain in the United States, and one of the great mountain peaks of the world, covering 200 square miles and rising 14,500 ft. above the waters of Puget Sound. That part of the mountain higher than 5,000 ft. above sea level is covered with snow and ice, and the precipitation resulting from the moisture-laden air of the Puget Sound region coming in contact with the glacial cold of the mountain sides, is estimated to average 140 ins. per annum. The fields of ice and snow which result from this precipitation are constantly moving down the mountain sides to the valleys about its base in the form of slowly moving glaciers many square miles in extent, which fill the valleys to the depth of hundreds of feet, and are constantly being added to from above and melting away below.

MOUNT RAINIER, THE HIGHEST MOUNTAIN IN THE UNITED STATES. ALTITUDE ABOVE SEA LEVEL, 14,500 FT.

View from Spray Park, on the Headwaters of the Puyallup River.

These great masses of ice increase in size and depth each winter and decrease by melting under the heat of summer, and the hottest and driest days of summer produce the greatest rate of melting. The Puyallup and Mowich Rivers drain a fan-shaped section of the mountain and five of the glaciers described, and thence each flows through mountain ranges, which add greatly to its volume, to a point of junction distant about 12 miles from the glaciers. The combined river is then known as the Puyallup. The water-shed of these rivers includes a rough and heavily timbered region not covered with ice or snow, and below the very high mountain range.

The streams of this lower timbered country are fed by the copious rains of the Puget Sound country which occur during the fall, winter and spring months concurrently with cool weather. During such cool weather the rain and the run-off in this timbered section is heavy and at the same time snow and ice accumulate on the mountain and the run-off from it is comparatively small. When the warm weather comes, the rain and the run-off from the timbered section is at a minimum and the melting of the snow and ice on the mountain and the run-off from the same is at a maximum. This balance, or alternation of the heavy run-off from the timbered and ice sections, results in a remarkably uniform flow in the river at the point from which the water is taken for power purposes and makes the operating conditions in using this stream ideal.

Although the dam and intake are located within 10 miles of the nearest glacier, the elevation at this point of diversion is only about 1,700 ft. above the sea level and the climate at this elevation is so uniformly mild and the water flows so rapidly that no ice comes down the river nor is formed either in the flume or reservoir.

UTILIZATION OF CURRENT.—The power is used for all branches of service—light, power and railway. It supplies the electric railway systems in Seattle and Tacoma aggregating 168 miles of trolley road, the multiple-unit, third-rail line between Seattle and Tacoma, two cable roads, one in Seattle and one in Tacoma, furnishes power for numerous factories, together with the shops of the Northern Pacific Ry., and the new pumping plant of the city of Tacoma, and supplies the greater portion of commercial and residence light-

ing and street lighting in Seattle and in the towns between Seattle and Tacoma.

Much of the power is distributed as alternating current, two-phase for power and single-phase for lighting, but there is also connected 10,000 KW. of converting capacity for producing direct current, 2,000 KW. of which is used for lighting and stationary motor supply. The bulk of the converting machinery (7,300 KW.) being of the synchronous type it is not necessary for the water power plant to generate or transmit idle currents.

The distribution of the current to the various localities and the transformation and conversion for various uses takes place at eleven substations containing 26,000 KW. of transformer capacity. Six of these are designed for transforming the 55,000-volt current to lower voltage, and eight contain machinery converting to direct current for railway use.

DAM AND INTAKE.—At a point one-half mile below the confluence of the Puyallup and Mowich Rivers, and about 1,700 ft. above sea level, is located the dam and intake of the Puget Sound Power Co. Here the water necessary for the operation of its plant is diverted by a low, solidly constructed dam, through a masonry intake to a flume which is constructed on the southwest side of the river for a distance of ten miles. The dam or diverting weir is 200 ft. long and 5 ft. high, and covers the bed of the river longitudinally for a distance of 60 ft., exclusive of the downstream apron. It is founded on an impervious bottom of clay hardpan and is made tight by three rows of triple-lap sheet piling set into the hardpan bottom and bedded in concrete. It is faced with 6 × 12 timber, covered at the crest with ¼-in. boiler plates, and besides the whole dam being a spillway there is a lower spillway 30 ft. wide to localize scour at the intake end. The intake is set at right angles to the dam and is constructed of concrete masonry. It is 62 ft. wide at the river bank and is protected by a screen grating made of iron bars ¼ × 4 ins. × 6 ft., spaced 2½ ins. apart. Provision is also made for the insertion of flash boards in grooves in steel frames in such manner as to regulate or entirely shut off the intake at a point between the river and the grating. A radial gate of unique design is also installed at the junction of the masonry intake and the flume for the purpose of quickly controlling the amount of water delivered to the flume.

FIG. 2. VIEW OF MOUNT RAINIER FROM THE TRANSMISSION LINE, JUNE 4, 1904.
In upper right-hand corner is seen the hill on top of which the reservoir is located, and the wagon road, cable incline, and pipes leading to power house in canyon.

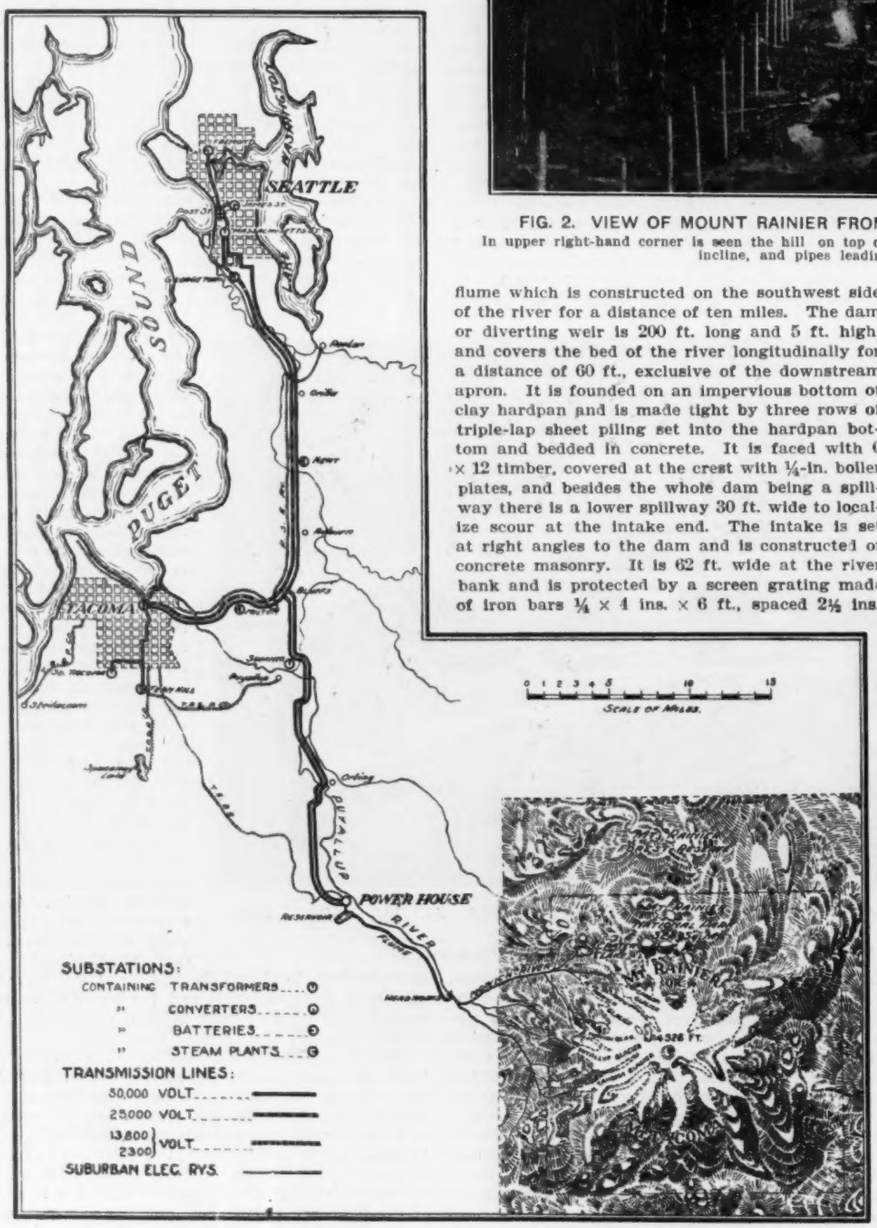


FIG. 1. MAP OF THE WATER-POWER ELECTRIC TRANSMISSION SYSTEM OF THE PUGET SOUND POWER CO.

FLUME.—From head works to reservoir, a distance of about ten miles, the water is carried in a flume, which as now constructed is 8 ft. wide and 5 ft. high, inside measurements, but is framed for the addition of plank to make it 8 ft. high. The flume is supported on low trestle, which follows the contour of the land. This trestle work is the same construction, and of equal strength to that usually used for railroads, and, in fact, during the construction heavy work trains were operated over its entire length. The flume proper is constructed of surfaced planks 2¼ ins. in thickness and 12 ins. wide, and the frames which surround it are spaced 4 ft. c. to c. It is built on a uniform grade of 7½ ft. per mile. Sand boxes and automatic spillways are provided at various points along the flume, and a number of gates are also provided for emergency use; a light railroad track for hand cars of standard gage is laid along the top of the flume to facilitate inspection and repairs.

All danger timber along the line of the flume is being removed and the flume trestle is built on rock or hardpan foundation, which protects it against trouble from slides. In constructing this flume the usual plan of building curves as a series of tangents was not followed, the bends in the flume are made with true curves presenting a uniform and smooth interior surface, and thus facilitating the flow of water.

RESERVOIR.—The flume discharges its water into a reservoir located on a high plateau, nearly 900 ft. above the power house. This reservoir serves as a relay to maintain the plant in continuous operation, in case of interruption of water supply, and also serves the very useful purpose of supplying water for temporary overloads in excess of discharge capacity of flume, or, in other words, for equalizing the daily fluctuations of load. The location of the reservoir is particularly well adapted for the purpose. The material excavated from the higher side of the site was used to form the embankment on the lower side of the

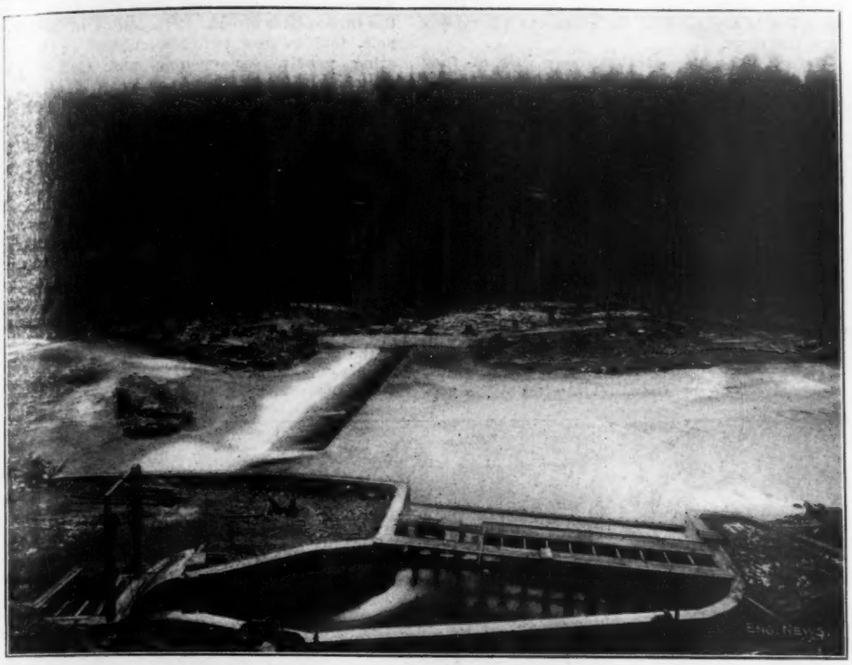


FIG. 3. DAM AND INTAKE ON PUYALLUP RIVER AT HEAD OF FLUME, APRIL 18, 1904.
Unfinished radial gate on the left.

reservoir. This material is a glacial boulder till of clayey consistency, which required blasting before it could be handled with steam shovel; it puddled well and formed a watertight fill, which set hard in embankment almost like concrete.

The flume enters one end of the reservoir, and, when the latter is drained as shown in the illustration, discharges into a concrete basin in front of the forebay. This arrangement permits the emptying of the reservoir for inspection or cleaning without interrupting the delivery of water to the power house, and distributes the water quietly to the penstocks without danger of carrying air into the pipes.

The forebay is of concrete, and is constructed inside of the reservoir, and is divided into compartments forming separate gate chambers for the main penstocks. Each compartment is provided with iron racks or screens with stop boards to permit inspection or repairs without emptying the reservoir. The gates are arranged for connecting an electric motor drive to be controlled from the power house.

The depth of water in the reservoir is at all times shown at the power house switchboard by a Dibble automatic electrical indicating and recording water gage fitted with low water alarm. This gage is operated by three wires running from a float-actuated Dibble transmitter located in the reservoir.

PENSTOCKS.—The penstocks, one for the two exciters, one for each of the four generating units now installed, and one for each of the remaining four units to be installed later, are carried through the reservoir embankment in the form of concrete-protected wood-stave pipes, joining the steel pipes just outside the reservoir embankment. Of the eight main pipes for the complete plant, four, together with the exciter pipe, are now continued about 1,700 ft. down an incline of about 30° to the power house on the river bank below. Each main pipe is of riveted steel, 48 ins. in diameter and ¼-in. thick at the upper end, tapering to 36 ins. in diameter and ¾-in. thick at the lower end, and was furnished by the Risdon Iron & Locomotive Works. The penstocks are anchored by massive concrete abutments, and all surface water is carefully drained away, and as a further security the pipes are protected with backfilling of earth, on which is planted quick-growing vegetation.

POWER HOUSE.—The power house is built in the bank of the river on a foundation of piling and rock; it is of massive concrete, brick and steel construction; the building for eight units will be about 100 ft. by 266 ft., divided longitudinally into two parts, a generator house and a transformer and switching house. The generating units are arranged parallel to and along the river side of the building, the penstocks being brought to them under the main floor from the rear. The transformers are grouped in isolated rooms of concrete in the basement of the switch house; the switching apparatus and wiring being in compartments overhead, as hereafter described.

WATER WHEELS.—Each unit consists of two overhung Pelton water wheels 10 ft. 6 ins. in diameter, mounted on each end of the shaft of each 5,000-HP two-bearing generator. The nozzles are of the needle type, arranged for automatic deflection by Lombard type "L" governor for speed control, the operation of the needles being only for economic adjustment of the discharge to the load of the machine. Each nozzle is also provided with a motor-operated gate valve for cutting off the water supply. The wheels have a maximum capacity of 7,500 HP. for each unit.

The wheels are arranged to be started and stopped and adjusted for speed from the main operating switchboard at one end of the generator room. Motor-driven pumps provide oil supply for ordinary lubrication, pressure oil for forced lubrication in starting and circulating water for cooling bearings.

FIG. 4. A VIEW ON THE FLUME LINE, SHOWING TEMPORARY TRACK USED FOR CONSTRUCTION, JULY 24, 1903.

FIG. 6. PACK TRAIN AT CAMP NO. 4, WITH DINNER FOR MEN AT CAMPS A, B, AND C, ON THE FLUME LINE, JULY 31, 1903.
Most of the men from this camp sleep on the works, and meals are carried to them on pack horses.

The rotors and wheels are hydraulically forced onto a 24-in. hollow nickel-steel fluid-compressed shaft. The spray from the wheel discharges, collecting in the water wheel housing, enters this hollow shaft and automatically serves to cool the bearings. At the date of their installation these were the largest impulse wheel units in the world.

GENERATORS.—There are four General Electric revolving field generators of 3,500-KW. capacity each, with an overload capacity of 25% for two hours, wound for three-phase current at 2,300 volts and a frequency of 60 cycles per second.

EXCITERS.—Two 150-KW. 125-volt 600-r. p. m. shunt-wound exciters are provided, each direct connected to an overhung Pelton water wheel and to a 2,080-volt 200-HP. three-phase induction motor. The wheels driving the exciters are not provided with automatic governors, and the direct-connected induction motors serve this purpose, operating either as motors or generators, according as they run below or above synchronous speed. The motors also afford a relay source of power for excitation in case of failure of an exciter water wheel or its water supply. Each exciter is capable of exciting six generators under all conditions.

TRANSFORMERS.—There are three banks of transformers installed at the power station, each bank consisting of three 2,333-KW. water-cooled, oil-insulated, General Electric transformers, with 25% overload capacity for two hours. Each bank has a capacity equivalent to two generators, the third bank being spare, so that the failure of even a complete bank would not diminish the capacity of the station. The transformers are connected delta on both the high and low tension sides and the arrangement of the windings is such that with 2,300 volts on the low tension side, high tension voltages of 27,500, 45,000 and 55,000 may be derived. These transformers have been operated at 55,000 volts from the beginning.

Water for cooling is derived from a spring above the power house, supplemented by connection with the reservoir. The transformers are piped so that the oil can be removed from the case into large storage tanks, and an emergency blow-off valve is arranged to discharge the oil quickly into the river.

Before filling these transformers with oil they were dried out at a temperature of 80° C. under a vacuum of 26 ins. for 10 hours. No oil was used that did not stand a potential test of 40,000 volts between ½-in. flat electrodes placed 0.2-in. apart. After filling and allowing the oil to thoroughly settle, samples of oil from bottom and top of each transformer were subjected to the above potential test, and no transformer was put into service until the oil passed this test satisfactorily.

ELECTRICAL ARRANGEMENT.—For connecting each generator and transformer bank to the low-tension bus-bars, and each transformer bank and transmission line to the high-tension bus-bars, a full complement of remote-control, motor-operated oil switches is provided.

There are two sets of 2,300-volt bus-bars, designated as the main and auxiliary busses. The main bus is for regular operation, while the auxiliary bus is for emergency operation, and for relaying the main bus in case of repairs to the latter. Both sets of bus-bars are identical and any generator and any transformer bank can be connected to either set.

Between each generator and each set of 2,300-volt bus-bars there are two sets of disconnecting switches and a triple-pole General Electric type "H" 1,200-ampere, motor-operated oil switch, a set of disconnecting switches being on either side of the oil switch. Between each set of bus-bars and each transformer bank there are two sets of disconnecting switches and a type "H" 3,000-ampere motor-operated oil switch, the arrangement being similar to that of the generator switches.

The purpose of the disconnecting switches is to remove the potential from the oil switches, that inspection of or repair to the oil switches may be safely made. The disconnecting switches are not to be operated when carrying current, except under emergency conditions. All ordinary switching is done by means of the oil switches, which simultaneously open and close the three lines of the three-phase circuit. In addition to the three-pole, double-throw switches mounted on the operating panels, for opening and closing these switches, when cutting in or out a generator or transformer bank, there is for each oil switch a clock-type, time-limit relay actuated by a secondary current from current transformers in circuit with that switch, these relays operating the motor connected to the oil switch in case of an overload or short-circuit lasting the period for which the relay is set. These relays can be set for overload periods of 4 seconds down to a small fraction of one second, it thus being possible to automatically localize short circuits on the system, and in apparatus, without completely shutting down the system. The electrical arrangement of the motors driving the exciters is the same as that of the generators.

There is one set of high-tension bus-bars, divided into three sections by sectionalizing switches, each transformer bank being connected to a corresponding section, and one line to each of the end sections.

Between the high-tension bus and each bank of transformers there are two sets of disconnecting switches and one triple-pole General Electric 60,000-volt 400-ampere motor-operated oil switch, a set of disconnecting switches being on either side of the oil switch. There are two outgoing high-tension lines and each line is controlled as just described for the transformer banks. All the high-tension oil switches possess the automatic features as described for the low-tension oil switches.

Lightning arresters without reactance coils are provided for each outgoing line.

Static dischargers are provided for the low-tension side of each transformer bank. These static dischargers consist of three 2,500-volt S. P. lightning arresters connected in star, the neutral point grounded. They limit the potential of the low-tension winding to 2,500 volts above ground, and would come into action in case of grounding

FIG. 5. A TRESTLE ON THE FLUME LINE IN PUYALLUP CANYON, BETWEEN CAMPS 4 AND 5, DEC. 31, 1903.

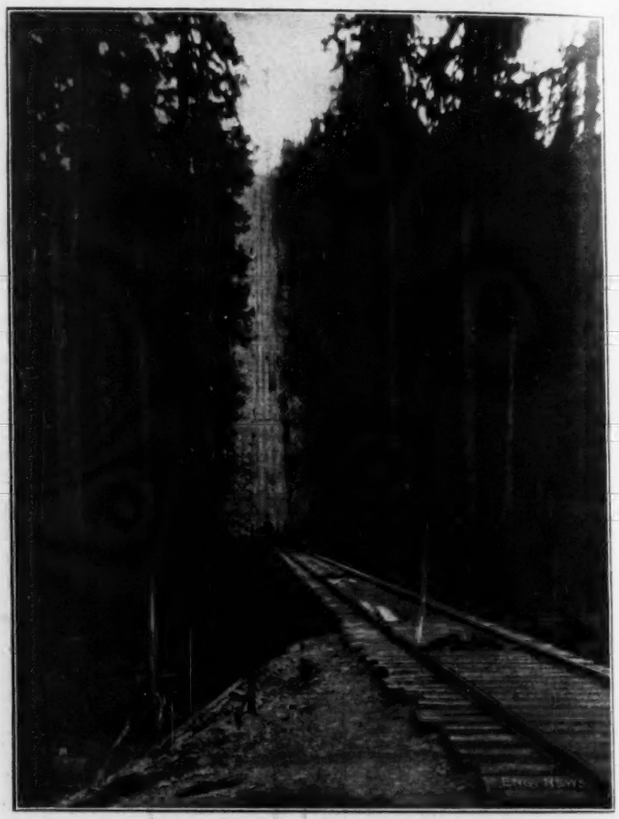


FIG. 7. CABLE INCLINE RAILWAY TO TOP OF RESERVOIR HILL. MAXIMUM GRADE, 68%. AUG. 3, 1903.

This railway was built to haul up material and supplies for building flume, reservoir, etc.

of one side of the transmission line or transformers.

The control of all the oil switches is from operating panels erected on a gallery in the east end of the generator room, at an elevation of 14 ft. above the generator room floor. The arrangement of panels from left to right is as follows:

Exciter panels, generator end.
Exciter panels, motor end.
Generator panels.
Totaling panels.
Generator panels.
Transformer control panels.
High-tension line panels.

The generator and exciter field-rheostats are hung below the gallery and are operated from pedestals by means of shafting and bevel gearing, the contact plates being on the rheostat boxes.

The highest alternating current potential on the switchboard panels is 115 volts, derived from potential transformers, and the highest direct-current potential is 125 volts, derived from the exciters.

Each generator panel contains three ammeters, one voltmeter, a polyphase indicating wattmeter, a polyphase integrating wattmeter, and a field ammeter.

Each outgoing line panel contains three ammeters, and the totaling panel contains a power factor indicator, a frequency indicator, a curve-drawing voltmeter and three curve-drawing ammeters. The curve-drawing instruments belong to a type lately developed by the General Electric Co., giving a record 3 ins. long per hour.

The plant is controlled entirely from the switchboard gallery. A water wheel may be started or stopped, a generator brought up to voltage, synchronized with other generators on either bus, a transformer bank cut in on either bus and a transmission line connected in circuit without the presence of a person in the room where the actual switching is done, the lighting of a red lamp indicating the closing of a switch and a green lamp the opening of a switch.

SWITCH-HOUSE ARRANGEMENT.—Figs. 13 and 14 show sections through the generator room and switch house. The transformer rooms are at the same level as the generator room, but isolated from the latter by rolling steel doors. On floor No. 2 are the low-tension disconnecting switches, the generator and transformer cables going to the sets of disconnecting switches on either side of the middle partition; the disconnecting switches installed between the oil switches and the bus, being on the outer walls and immediately below the bus-bar compartments, which are above on floor No. 3. In the center of floor No. 3 are the low-tension oil switches, the two oil switches corresponding to a generator or transformer bank being arranged back to back and facing their corresponding set of bus-bars. The bus-bars are of the laminated type, consisting of flat copper bars with expansion joints, and supported on marble slabs set on edge, which in turn rest on concrete slabs forming barriers between adjacent bus-bars The compartments formed by the concrete slabs are to be covered by insulating fireproof doors.

The oil switches are installed in brick cells with soapstone bottom and top slabs and doors. Each pole of a switch is separated from the other poles by brick barriers.

The same general scheme is used for both the low and high-tension disconnecting switches and oil switches, except that only one set of high-tension bus-bars is at present installed, provision being made for the later installation of the second set. The high-tension disconnecting switches and current transformers are on floor No. 5, while the high-tension oil switches are on floor No. 6. Above floor No. 6 are the two outgoing high tension line towers, in the north end of which are the high-tension lightning arresters, each pole being separated from its adjacent pole by brick barriers extending the full length of the arrester. The lines emerge from the wire tower centrally through an extra heavy 30-in. sewer tile, covered by a glass plate.

TRANSMISSION LINE. — From the power house two parallel transmission lines run a distance of 22 miles to Bluffs, a station on the line of the Puget Sound Electric Ry., 9 miles from Tacoma, and 25 miles from Seattle. From Bluffs one line runs for a great part parallel to the transmission line of the Puget Sound Electric Ry. to Seattle, and one to Tacoma, also parallel to the transmission line of the Puget Sound Electric Ry.

The transmission line of the Puget Sound Electric Ry. is at present operating at 27,000 volts, but the line is designed for operation at double this voltage, so that when this line is changed over to

FIG. 8. RESERVOIR AT HEAD OF PIPE LINE NEARLY COMPLETED, APRIL 18, 1904.

Flume at the right is delivering water to forebay pool sufficient for 5,000 HP. Rock has been piled on flume foundations to prevent floating as reservoir is filled.

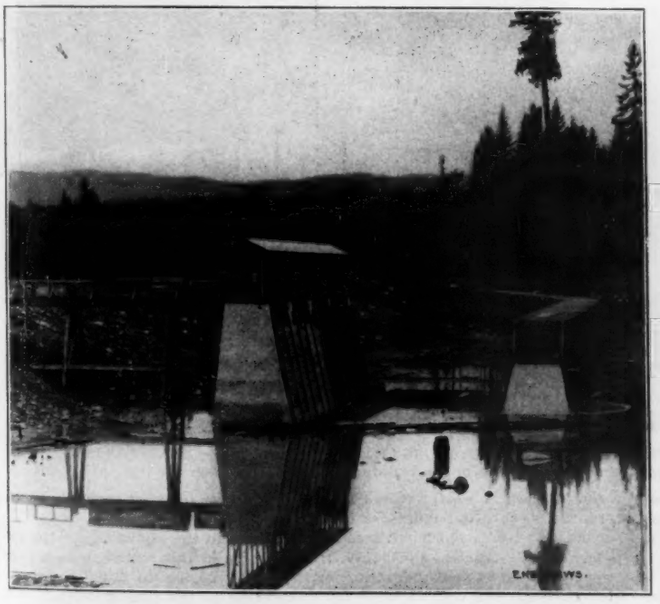


FIG. 9. INTERIOR OF RESERVOIR DURING CONSTRUCTION SHOWING POOL ARRANGEMENT FOR TEMPORARILY UTILIZING WATER BEFORE COMPLETING RESERVOIR. APRIL 18, 1904.

FIG. 10. SPILLWAY REGULATING HEIGHT OF WATER IN RESERVOIR. APRIL 18, 1904.

This spillway forms a part of the flume at its entrance to the reservoir. When the high-water level in the reservoir is reached, the water overflows the sides of the flume as shown and is carried off to a wasteway.

a 55,000-volt basis there will be two complete and independent pole lines from the power house to Seattle and Tacoma. At Bluffs there are erected junction pole switches, by which the two transmission lines may be cut through independently, one to Seattle and one to Tacoma, or both lines put in multiple, or any section isolated without interfering with the operation of the other sections.

From the power house to Bluffs a private right of way has been secured, the two pole-lines being from 70 to 80 ft. apart. When passing through wooded sections all dangerous timber has been cleared back on the land adjacent to the right of way on both sides, so as to completely protect the transmission line.

The minimum length of poles used was 45 ft., with a minimum top diameter of 10½ ins. The standard spacing is 125 ft. on straight line and 90 to 100 ft. on curves. The main crossarm is 5 × 7 ins. × 7 ft. 4 ins., Washington fir, boiled in raw linseed oil, giving it a much longer life than an untreated arm. This arm is bolted to the pole by two galvanized iron bolts and braced by a combination wood and galvanized iron brace. At the top of the pole is a 5 × 7 × 18-in. arm supported by an angle iron frame bolted to the pole by two galvanized iron bolts. The main arm supports two insulators, and the top arm one insulator, giving an equilateral triangular spacing of 72 ins. between wires.

The pins on one line from the power house to Bluffs and from Bluffs to Seattle and Tacoma are galvanized malleable iron, cast hollow, circular in cross-section, and having a shank diameter of 1⅛ ins. The pins on the other line are of the same general exterior form and dimensions, but turned from eucalyptus wood and treated with linseed oil. The iron pins and eucalyptus pins are entirely interchangeable in all parts of the construction.

The insulators are of dark brown glazed porcelain, a small portion being furnished by the Locke Insulator Mfg. Co., and the greater portion by R. Thomas & Sons. The insulators are a special design, adopted after tests on a number of samples of varying design. The insulator consists of a broad umbrella-shaped top, 14 ins. in diameter and three inner shells cemented together and to the iron pins by neat Portland cement. They weigh about 22 lbs. and stand a potential of 90,000 to 100,000 volts before arcing over under an artificial rain test. The separate parts of the insulators were given a dry potential test at the factory before shipment, and after assembly in Tacoma and before shipping out on the line they were again tested to a potential corresponding to the dry arcing-over voltage. So far the behavior of these insulators under the weather conditions that have existed since the plant was put into operation, and under a line voltage of 55,000 volts, has been entirely satisfactory.

The line wire on both lines from the power house to Bluffs and from Bluffs to Seattle is 19-strand No. 0000 semi-hard drawn copper cable, and from Bluffs to Tacoma is solid No. 0 semi-hard drawn copper wire. The wires are transposed, making a third of a turn about every four miles.

The telephone line is supported on crossarms 7 ft. below the main arm and consists of two No. 10 hard drawn copper wires, transposed every tenth pole, the glass insulators being double petticoat deep groove on locust pins. The operation of the telephone line with the above construction has been entirely satisfactory. The company also has an independent telephone line leased from the Sunset Telephone Co. and constructed over another route.

SUMNER AND PUYALLUP.—Eighteen miles from the power house and along the transmission line from the power house to Bluffs is the town of Sumner. In Sumner has been built a substation to accommodate 2 100-KW. 50,000 to 2,300-volt transformers for local power and lighting. At present only one transformer has been installed, furnishing current for lighting Sumner.

A 2,300-volt line will be built from Sumner to Puyallup, a distance of three miles, for supplying the city of Puyallup with current for lighting and power, taking the place of the steam plant at present in operation.

MASSACHUSETTS STREET SUBSTATION.—The receiving station in Seattle is built on Massachusetts St., near the southerly city limits. Here the high-tension current is stepped down to 2,300 volts for local distribution to the stations of the Seattle Electric Co.

Control is provided for the two incoming high-tension lines by means of high-tension motor-operated oil switches, and for two 4,000-KW. banks of transformers and for three outgoing 2,300-volt feeders. The control of the transformers consists of a motor-operated 60,000-volt 400-ampere oil switch on the high-tension side of each bank of transformers and a motor-operated 2,500-volt 4-pole oil switch on the low-tension side of each bank. The control of the 2,300-volt outgoing feeders is by motor-operated 4-pole oil switches similar to the transformer low-tension switches, differing only in capacity, the former being 800 ampere and the latter 1,200 ampere capacity. All of the oil switches have time-limit relays for automatically opening the switches in case of overload or short circuits. There are installed four 2,000-KW. transformers in two banks of two each, transforming from 50,000 volts three-phase to 2,300 volts quarter-phase. The arrangement of the windings is such that 50,000, 40,000 and 25,000 volts can be used on the high-tension side, and low-tension voltages of 13,800, 6,900 and 2,300 volts may be obtained. The two transformers constituting a bank are connected in T, but using the full winding in the teazer transformer rather than 87%, as in the usual Scott three-phase two-phase connection. This produces only [illegible] volts on the low-tension side of the teazer transformer, with 2,300 volts on the main transformer, and in order to boost this to normal a 2[illegible] V. transformer called a compensator, having the full ampere capacity, in the boosting coil, of the [illegible] KW. transformer, and a ratio of transformation of 1990-310, is installed. This makes it possible to omit all 87% taps on the high-tension winding, of which there would be a number, for the same primary voltages above stated, and simplifies the transformer construction.

All the transformers, including the compensators, are water cooled, the water for cooling being primarily derived from the city service, but recooled by a cooling tower to effect economy by the re-use of water.

There is in addition to the above apparatus two 500-KW. transformers in this station with a ratio of transformation of 25,000 to 2,200 volts, installed for connection to the transmission line of the Puget Sound Electric Ry.

For measuring the input of power into the 2,300-volt busses, a graphic recording voltmeter, ammeter and wattmeter are provided in addition to the integrating wattmeter. Lightning arresters identical with those at the power house are provided for each of the incoming lines. Marble barriers between adjacent poles of the arresters are installed to prevent the traveling of an arc from one leg to another. Four-pole static dischargers are installed on the low-tension side of each transformer bank, their purpose being the

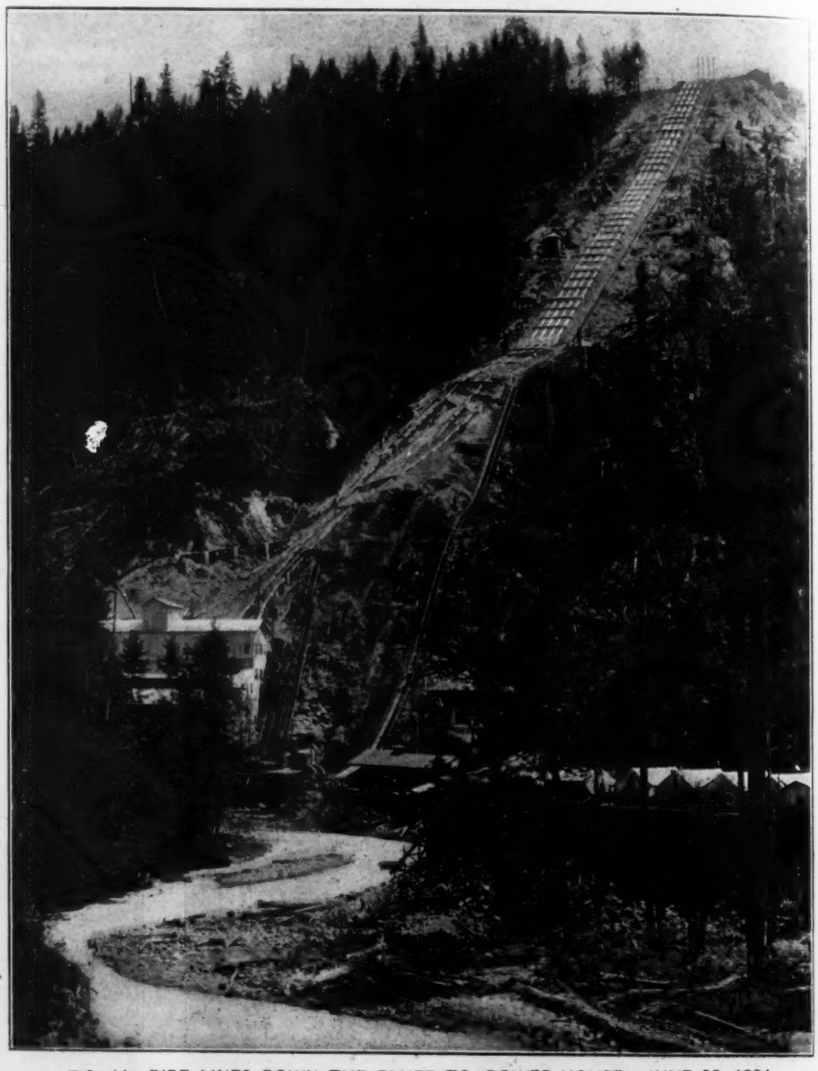


FIG. 11. PIPE LINES DOWN THE BLUFF TO POWER HOUSE. JUNE 26, 1904.
The Superintendent's cottage and Camp No. 9 of the construction force are seen in the right foreground.

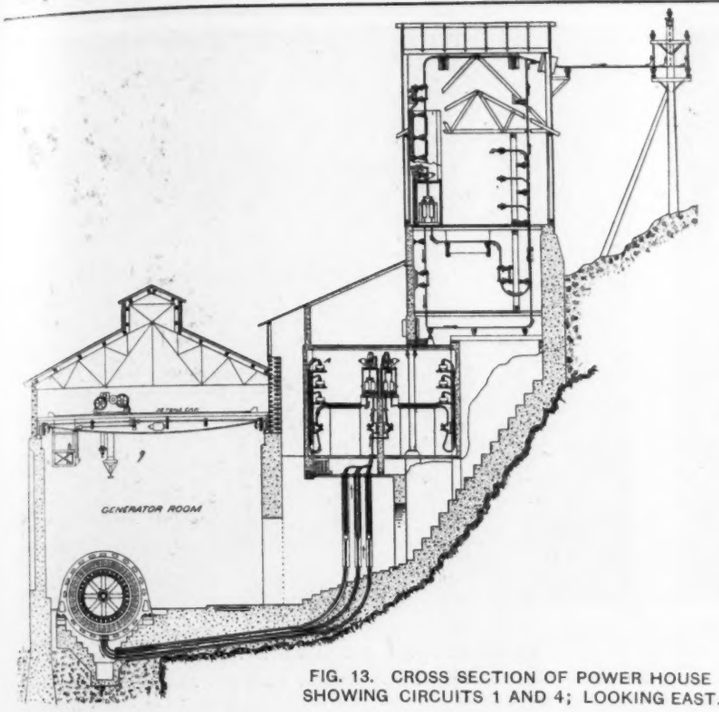


FIG. 13. CROSS SECTION OF POWER HOUSE SHOWING CIRCUITS 1 AND 4; LOOKING EAST.

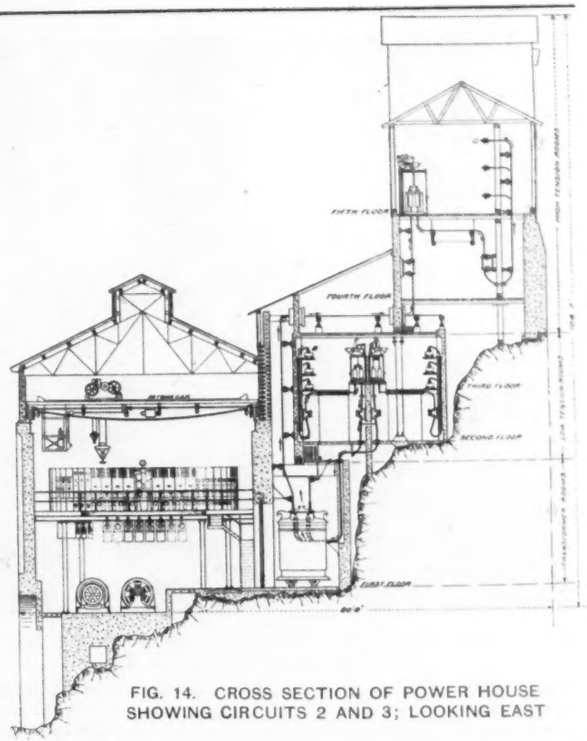


FIG. 14. CROSS SECTION OF POWER HOUSE SHOWING CIRCUITS 2 AND 3; LOOKING EAST

same as those at the power house. For controlling the voltage of the 2,300-volt outgoing feeders, there is installed in each feeder a motor-operated induction regulator, each of a capacity of 340 KW. These regulators boost or lower equally each leg of each phase.

SEATTLE ELECTRIC CO.'S DISTRIBUTION.—The power is transmitted at 2,200 volts, two-phase, from the Massachusetts St. substation to Post St. station, and from there also at 2,200 volts, two-phase, to James St. station and Fremont substation.

Post St. station contains nine 500-KW. rotary converters, each with two 300-KW. transformers, five giving 500-volt current for railway, and four 250-volt current for lighting; also six 50-KW. tub transformers for street lighting. This station is a steam relay station, and contains two 2,500-KW. overload capacity, 60-cycle, 2,200-volt, two-phase alternators, each driven by a vertical compound McIntosh & Seymour engine; also a 1,000-KW. lighting and a 500-KW. railway storage battery. This station contains the general switchboard for controlling the whole distribution in Seattle.

James St. station contains two 300-KW. induction motor generator sets, giving 500-volt railway current. It is also a steam relay station, with three 150-KW. railway generators, driven by a double Corliss engine. When operated on a water power basis the railway generators are used as motors to operate the James St. cable road.

Fremont substation contains two 300-KW. motor-generator sets, one induction and one synchronous, the motor end of each being 2,200 volts, two-phase, and the generator end 500 volts direct current. There is also installed a 300-KW. railway storage battery.

The Seattle Electric Co. has in addition to the above two steam relay stations not used as substations. These are equipped with direct-current machinery for railway and light, and have a combined capacity of 1,500 KW.

TACOMA SUBSTATION.—The receiving station in Tacoma is a new brick building, built adjacent and as an addition to the steam station of the Tacoma Railway & Power Co. Control for two incoming high-tension lines is provided, as described for the Massachusetts St. substation. One 4,000-KW. 50,000 to 2,300-volts transformer bank is installed with automatic oil switch control on high and low-tension sides.

There are also installed two 500-KW. step-up transformers, transforming from 2,300 volts two-phase to 13,800 volts three-phase for supplying power to Fern Hill substation, the Northern Pacific Railway Co.'s shops, and other local consumption not within the range of economical distribution at 2,300 volts. Automatic control of this bank is provided on the low-tension side only by means of a type "H" four-pole motor-operated oil

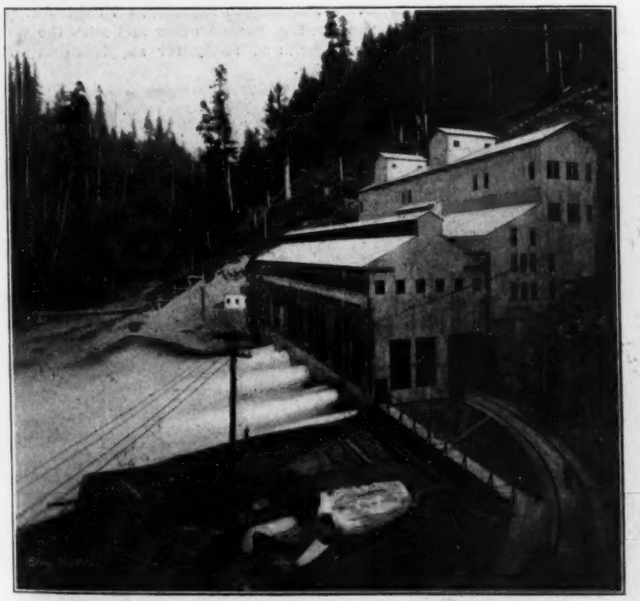


FIG. 12. VIEW OF LOWER END OF POWER HOUSE SHOWING FOUR UNITS IN OPERATION.

View shows temporary end wall in place and grading and trenching to right for extension of power house to install four additional penstocks and generators.

FIG. 15. START OF 55,000-VOLT TRANSMISSION LINE FROM POWER HOUSE.

Wires pass out of towers through tile pipes. Triple-petticoat insulators shown on poles in upper left-hand corner.

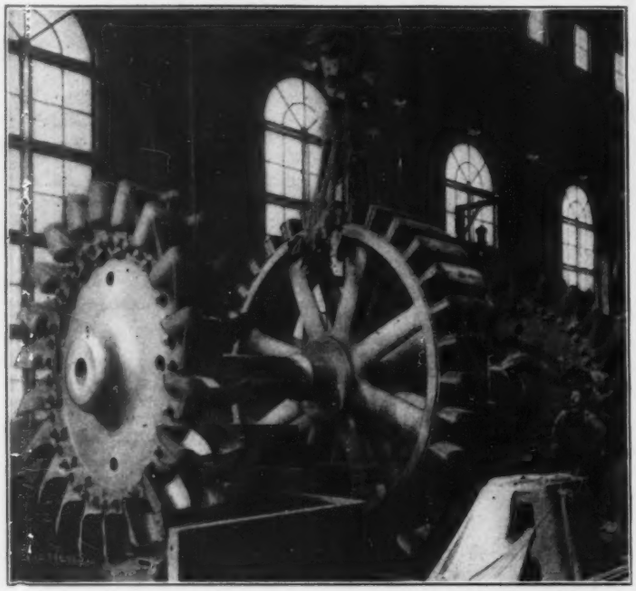


FIG. 16. PLACING 5,000-HP. ALTERNATOR AND PELTON-WHEEL UNIT IN SHAFT BEARINGS, JUNE 8, 1904.

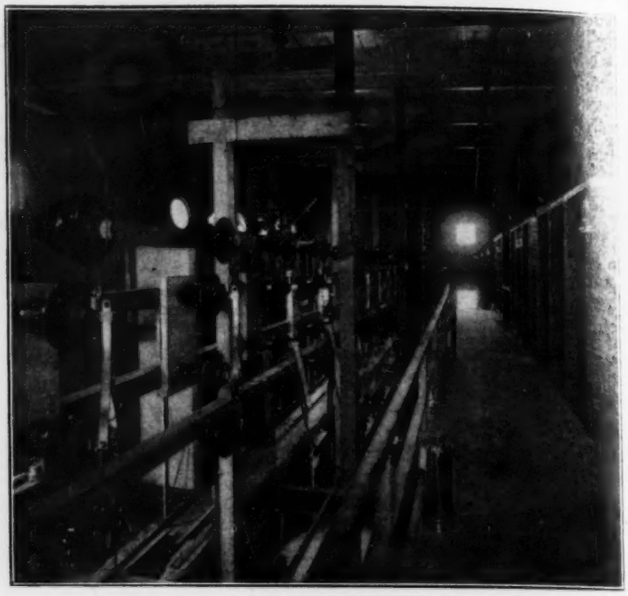


FIG. 22. HIGH-TENSION WIRING AND DISCONNECTING SWITCHES IN MASSACHUSETTS ST. SUB-STATION, SEATTLE.

switch. Spare transformers for each of these banks are provided.

For receiving power from the 25,000-volt transmission line of the Puget Sound Electric Ry., four 200-KW. oil-cooled transformers, wound for 25,000 to 50,000 volts, stepping down from 25,000 to 2,300 volts, are installed.

The high-tension oil switches are installed on a reinforced-concrete gallery 20 ft. above the transformer room floor, the two-line oil switches on a gallery at right angles to the length of the building, and the transformer switch on a gallery parallel to the length and along the north wall of the building. Directly under the transformer oil switch are the transformers themselves. On the opposite side of the room and parallel to its length and four ft. above the floor are the transformer 2,300-volt oil switches.

One 400-KW. induction regulator, similar to those installed in the Massachusetts St. substation, controls the potential of the supply bus, being installed between the transformer bus and the supply bus. Apparatus for cooling the transformer circulating water is being installed somewhat similar to that at the Massachusetts St. substation.

The 2,300-volt power is used for lighting and power service in the city of Tacoma partly, and partly converted into 600-volt direct-current for railway and commercial motor service. This conversion is effected by two 500-KW. induction motor-generator sets, by one 850-KW. synchronous motor set, and by 800 KW. in belted machines, driven by a 1,000-KW. synchronous motor. Either this synchronous motor or the 1,000-KW. motor driving the 850-KW. direct-current generator can be driven by the steam engines, which drive onto a line shaft in which these motors are set, being connected at either end by jaw clutches, thus furnishing a supplementary source of supply and reserve for any of the alternating current distribution, and for the induction motor generator sets supplying current for the railway. A 100-HP. induction motor furnishes power for driving a cable road accommodating the hill district of the city.

The Tacoma Railway & Power Co. operates about 84 miles of track in the city of Tacoma and between Tacoma and the neighboring towns of Puyallup, Spanaway and Steilacoom, and also furnishes power for the operation of the trains of the Puget Sound Electric Ry. within the Tacoma city limits.

At the Fern Hill junction of the Puyallup and Spanaway lines is a steam station of 500 KW. capacity. There is being installed in this station a 500-KW. synchronous motor-generator set, supplied from the substation above described by a 13,800-volt transmission line. This same transmission line supplies current for the operation of motors and lights at the shops of the Northern Pacific Ry., at South Tacoma, and for the operation of induction motors driving air compressors working a Pohlé air-lift system pumping water for the Tacoma City Water supply, near South Tacoma, and for operating a large number of other stationary motors used by various manufacturing concerns.

SYSTEM OF PUGET SOUND ELECTRIC RAILWAY.—The Puget Sound Electric Ry. operates an interurban third-rail system between Seattle and Tacoma, traversing the White River Valley, a distance of 36 miles, and also a branch line reaching the town of Renton. 600-volt direct curent is supplied to the third rail through three substations located at Georgetown, Kent and Milton.

Each substation contains a bank of transformers, stepping down from 25,000 volts three-phase to 2,300 volts two-phase; also a 300-KW. induction motor-generator set; and a storage battery having a rating of 384 KW. on the hour basis. Oil switch control is provided on both the high and low-tension sides.

From Kent substation is operated the city lighting systems of Kent and Auburn, a transformer, separate from those feeding the motor-generator set, being provided for supplying this 2,300-volt service.

These substations are supplied from the 25,000-volt transmission line, previously mentioned, this line having the 25,000-volt transformer relay at both the Seattle and Tacoma ends. When this line is operated at 50,000 volts, transformers for this voltage will be installed in all the substations.

AUXILIARY AND RELAY APPARATUS.—The electrical development has been designed primarily to insure uniform and uninterrupted service. Continuity of service has been insured by the greatest solidity of construction in every part; by duplicate busses and switches at the power house, duplicate transmission lines and spare transformers at each end of the transmission line, so that all repairs can be made without discontinuing service and by having in all the electrical machinery an overload capacity of from 25% to 50%.

In addition to this there are in reserve in Seattle and Tacoma six steam plants of 10,000 KW. aggregate capacity and six storage batteries of 2,700 KW. aggregate capacity, all electrically interconnected with each other and with the water power plant, and ready for supplementary and relay service.

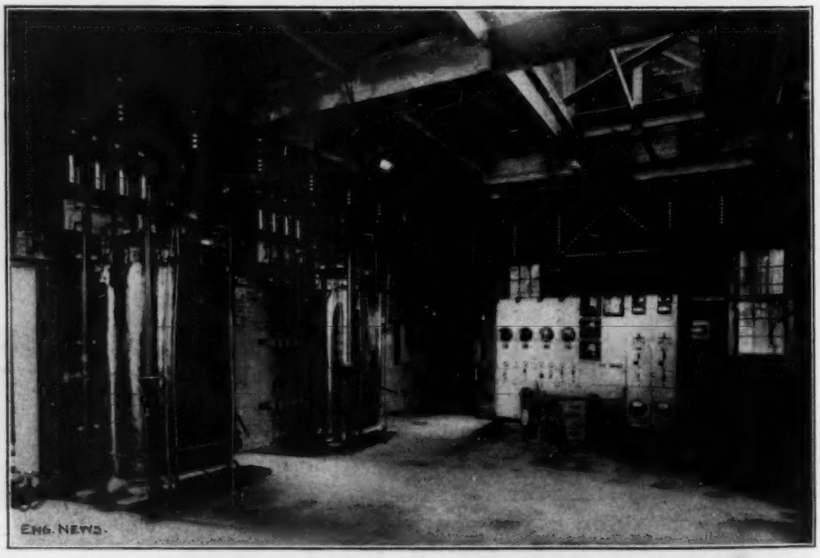


FIG. 23. SWITCHBOARD AND COMPENSATORS IN MASSACHUSETTS ST. SUB-STATION.

THE CABLE INCLINE OF THE PUGET SOUND POWER CO.

In addition to the information given in the preceding article our contemporary, "The Engineer" of London, has just published an article giving some notes of experience of an engineer employed on the construction of the Puget Sound Power Co. plant. We take from this the following extract describing the remarkable cable incline by which material was hoisted to the reservoir site:

FIG. 21. FIFTH FLOOR OF CONCRETE SWITCH HOUSE.

High-tension sectional bus-bar on the left. High tension switch cells governing high-tension transformer and transmission circuits at right.

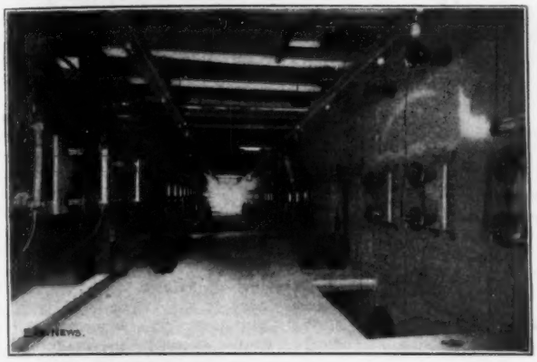


FIG. 20. FOURTH FLOOR OF CONCRETE SWITCH HOUSE.

View shows Current Transformers for instruments and high tension disconnecting switches for insulating oil switches on floor above.

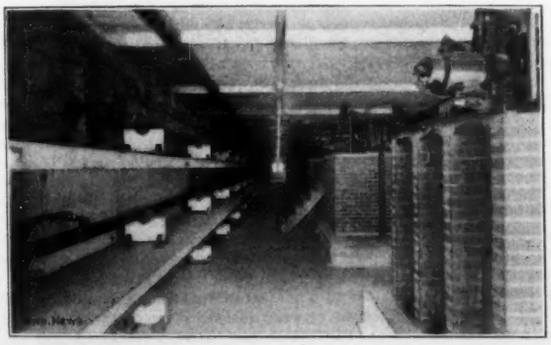


FIG. 19. THIRD FLOOR OF CONCRETE SWITCH HOUSE.

At the left is a set of 2,300-volt bus-bars with concrete barriers. At the right are remote-control 2,300-volt oil switches.

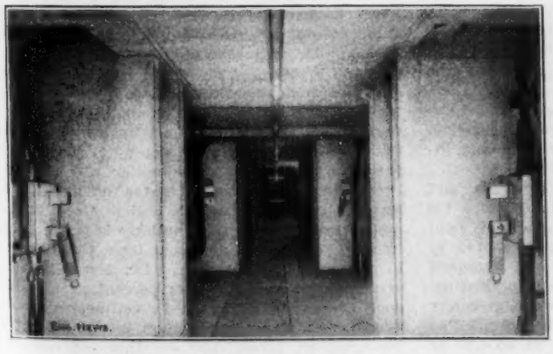


FIG. 18. SECOND FLOOR OF CONCRETE SWITCH HOUSE.

At right and left are seen the 2,300-volt disconnecting switches below the oil switch room. Concrete barriers are placed between switches.

The incline leading from Electron to the reservoir site was 4,600 ft. long. As the lower end was in heavy rock cutting, while the upper was clay and hardpan, it was built as a Y, the two tracks being from near the middle to the summit, in order that a descending car might assist the ascending one upon this, the steepest part of the grade. Commencing at the bottom, the grades ranged from 26%, through 5 and 3% in the middle, to 37% at the wagon road crossing, and reached the summit by some 1,500 ft. at no less than 67½%, which is believed to be a "record."

The hoisting engine at the top was able to bring a standard flat car, weighing 18,000 lbs., up this hill, but the road was regularly operated with small flat cars, built on the works, with 15 ft. bodies, equipped with a "strong back" frame at one end. A large double-cylinder donkey engine was later placed at the passing point—called the "Midway Plaisance," after the Chicago Fair—which brought standard cars, flat and box, half way, where they were unloaded on to the small cars. The standard cars could not descend the 3% grade and pull the rope, and as the "Midway" was all on a 30-ft. trestle, that grade could not have been much increased without considerable extra outlay. All the trestles were made with the round timber found on the ground, up to and including the caps. The rest of the track was laid on heavy hewed ties, cut locally, and sunk in the hardpan to formation level. To anchor the track on the 67½% grade a line of stringers, half-lapped to each other at their butting ends, was laid continuous under each rail, with which they broke joint, and to the stringers were bolted 6 × 8-in. sawed ties, every fifth one of which are turned on edge and let 2 ins. into the stringer. The 60-lb. rails were spiked to these, the flanges being notched at every fifth tie and the spikes driven in these notches to prevent creeping. The track so constructed stood perfectly, despite many gloomy prognostications. Much trouble was experienced from washing out of the roadbed in the heavy storms, when large quantities of water would rush down in a torrent, but cross trenches, connecting the side drains at very short intervals, cured this trouble. It was difficult for a man to get up this grade at any time, but absolutely impossible to stand up on it during rain.

The rope used was 1⅛-in. plough steel, and when the operating foreman had surreptitiously satisfied himself that he "couldn't break it"—by taking up a flat car, loaded with ties, stringers and rails—nobody hesitated to trust himself to it on the trip. The descent at night, when cars were being lowered as fast as they would run, was something to remember. On one occasion, when the steam shovel for the excavation of the reservoir was going up, a coupling chain—not the rope—broke when it was near the top. The car went down at speeds estimated variously between 90 and 200 miles an hour, keeping the rails the whole way to the bottom, where it met the engine used to work over the power-house line standing on the track at Electron. The crew saw what was coming in time to jump, and escaped with trifling injury; but the locomotive was thrown fully 200 ft. into the air, where she blew up—what was left of her, that is. She was the worst wrecked engine the writer ever saw.

The small cars, of which some forty in all were built, were usually run in trains of three or four at a time, being loaded at the "Midway" from standard cars brought up by the donkey engine, or from the stock of lumber generally kept stored there. They were fitted with hand brakes of the English goods wagon type, for ready control in marshalling on the 3% grade, and proved to be just what was required for the sharp curves of the flume.

The whole length of the incline was lighted by electricity from the service plant, and was operated strictly by telephone, helped out by a man in a crow's nest at the top, who was in view of the engineer running the hoist. The rope was carried on cast-iron sheaves, or rollers with wooden barrels, and was lubricated with tar and linseed oil. Had it been run to the lower end of the incline it would have necessitated arrangements to take care of a vertical rise at the "Midway" of over 100 ft.

The road was worked day and night, and transported about eight million ft. of lumber, in addition to the daily supplies for 2,000 men, and the boilers, machine tools, electric light engine and dynamo for the construction plant, as well as a large proportion of the steel pipe lines and a vast quantity of miscellaneous material required for the ten miles of railway and three "dinky" locomotives used on the flume work. No accidents occurred, other than the breakaway previously mentioned. The total lift was just under 900 ft., and at the top the tracks, after crossing the pipe lines, joined the flume railway, and connected with various spurs to the company's commissary store at Reservoir Camp and to sawmill No. 1. Immediately beside the hoisting engine house were the four boilers, provided with a spur track from the mill, and the machine shop and dynamo room. Here were installed planers, shapers, drill presses and the usual appliances of a well-equipped shop, all run from the electric light engine. Ample stores were also built here, where stocks of material and tools were kept, being duly charged out to the several departments and crews as required. Current was furnished to the sawmill, to the reservoir camp, along the incline, and for the use of the contractors for the power house and reservoir.

Spring catch points were provided at the head of the incline, which were set by hand for every descending train. The time required for a work trip, ascending, was usually about 16 minutes.

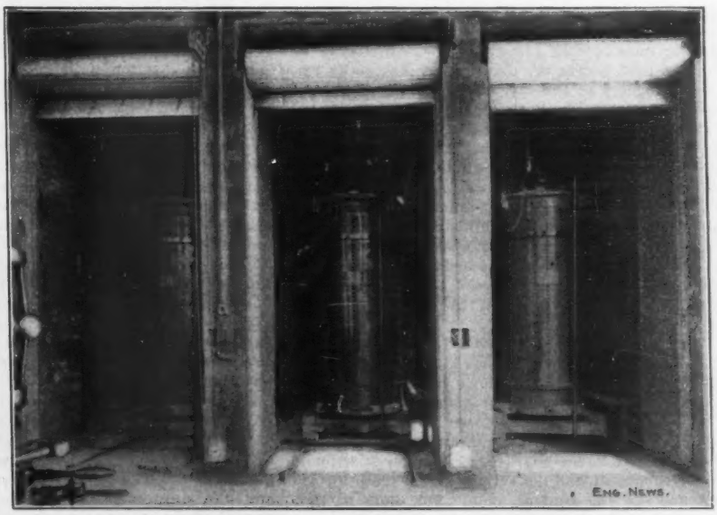


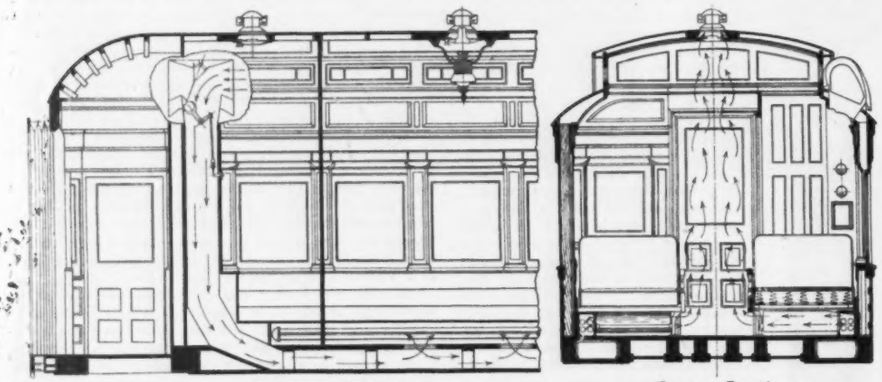
FIG. 17. GROUP OF STEP-UP TRANSFORMERS ON FIRST FLOOR OF POWER HOUSE.

There are three of these groups, each group consisting of three 2,300-KW., 2,300-55,000-volt transformers. Each group of three transformers is placed in a concrete cell with concrete and brick vent through its roof. Entrance to the cell is protected by rolling iron shutters.

THE PASSENGER CAR VENTILATION SYSTEM OF THE PENNSYLVANIA R. R.

Three years ago, in our issue of June 13, 1901, we briefly described a system of ventilation for passenger cars developed by the motive-power staff of the Pennsylvania R. R. Since that date the system has been put into extended use, so that at the present time over a thousand passenger cars on the Pennsylvania R. R. are equipped with it, and a number of cars on other roads have also been equipped.

A pamphlet describing the system, written by Dr. Chas. B. Dudley, has just been published by the Pennsylvania R. R. Co., and it constitutes, we feel safe in saying, probably the best and so far as we recall the only treatise on car ventilation in the language. The pamphlet is of the 6 × 9 in. standard size, and contains some 24 pages, with plates illustrating the system and its operation.



CROSS-SECTION AND PARTIAL LONGITUDINAL SECTION OF PASSENGER CAR, SHOWING VENTILATION SYSTEM OF PENNSYLVANIA R. R.

Some of the features of greatest interest in the pamphlet we have abstracted as follows:

The normal capacity of an ordinary passenger car is taken as 4,000 cu. ft., and it is assumed to carry 60 persons. Standard authorities on ventilation set 3,000 cu. ft. of air per person per hour as the quantity required for good ventilation. It it were attempted to give such ventilation in an ordinary passenger car, it would mean the passage of 180,000 cu. ft. per hour through it, or an entire change of the air in the car every 80 seconds. To warm such a volume of air in severe weather and to get it into and out of the car without disagreeable and dangerous drafts appeared to be so nearly impossible that the quantity was cut to one-third the above-named figure. In other words, the system is designed to deliver to the car 60,000 cu. ft. of fresh air per hour.

The air is taken in through two hoods with flaring mouthpieces placed on the lower part of the car roof, beside the monitor, on diagonally opposite corners of the car. These hoods open into downtakes, by which the air passes to flues located on each side underneath the car floor and 14 × 7½ ins. in cross-section. These flues extend the whole length of the car, and openings at intervals permit the air to pass upward, over the steam heating pipes and into the car. The vitiated air is exhausted from the top through seven 6-in. Globe ventilators, one over each lamp and one at each end of the car. The deck windows in the monitor are permanently closed and the system is intended to operate without the opening of any of the car windows.

The cross-section and partial longitudinal section of the car herewith, reproduced direct from the engravings in Dr. Dudley's report, will serve to explain the general operation of the system. The heating pipes are enclosed in a continuous boxing 5½ × 8½ ins., in cross-section inside. From these heated boxes galvanized iron pipes extend under each seat and deliver the warm fresh air at the floor in the central aisle. The slots in the floor by which the fresh air passes from the underneath flue up into the heater box are 2 × 12 ins. in size, and are placed midway between the seats, so that the air passes both ways from each aperture through the heater box to the adjacent heater pipes; and this amount of contact is found to sufficiently warm the air even in severe weather.

The downtakes have each a cross-section of about 100 sq. ins., and the faces of each hood are covered with wire gauze to exclude cinders which might be large enough to start fires. Smaller cinders are deposited on the bottom of the air flues under the car floor and doors are provided whereby these may be cleaned out when necessary. The downtakes are provided with valves which may be closed by the trainmen to exclude smoke in passing through long tunnels. The Globe ventilators on the roof of the car are made adjustable, so that the quantity of air exhausted from the car can be reduced if necessary, when few passengers are in it, or when the locomotive is detached and it is desired to retain heat in the car.

Regarding the amount of steam required to warm the cars by this system, Dr. Dudley states that no very positive data have been obtained. A very simple calculation, however, shows that the expense on this score need not be excessive.

If we assume 60,000 cu. ft. of air per hour to enter the car, its weight will be (at 13 cu. ft. = 1 lb.) 4,600 lbs. To heat this air in zero weather to 70° F. will require (taking specific heat of air as ¼) $4,600 \times 70 \times \frac{1}{4} = 80,500$ heat units.

If the locomotive uses coal of 13,000 h. u. calorific value and converts 50% of this into steam, the total coal consumption per car per hour due to the heating system, would be $80,500 \div 6,500 = 12\frac{1}{2}$ lbs. It will be apparent from this that no excessive expense is involved in heating the air to furnish satisfactory ventilation in railway passenger cars.

THE INTERNATIONAL ELECTRICAL CONGRESS.

One of the largest and most important (and also most successful) of the technical conventions held in connection with the St. Louis Exhibition was the International Electrical Congress, which continued through the six days of Sept. 12 to 17. This Congress was organized more than a year ago, under the auspices of the exhibition management, and comprises some 2,000 members, 25% of whom are in foreign countries. The purpose was to hold a joint meeting of electrical engineers from all parts of the world, and nine American and six foreign societies united to aid in the work; 15 governments, including that of the United States, also appointed special delegates. The number of persons officially registered as in attendance was over 750, and this list included the names of many American and foreign electrical engineers and scientific men of national and international reputation.

About 170 papers were on the program, and nearly 100 of these were printed in advance for distribution at the meeting, but some were read by title only. Other papers were presented in manuscript. The meetings were well attended and the discussions were long and interesting, the members showing no disposition to give any subject a merely perfunctory consideration. The meetings lasted from 9.30 or 10 a. m. to 1.30 or 2 p. m., the afternoons and evenings being devoted to visiting the exhibition and attending various social functions. During the entire week special displays were made in the Electrical Building of the exhibition.

Excellent arrangements were made for carrying on the work. The Congress divided into eight sections, for different branches of the general subject, and these held meetings in separate rooms. Of course, many members would have liked to attend the meetings of more than one section, and this led to a considerable amount of walking to and fro, as members tried to find what papers were being considered in the different rooms. This, however, could not well be avoided, and in some cases joint meetings were held by two sections to consider papers of equal interest to both. One somewhat unfortunate feature was the fact that several of the rooms were separated from each other only by screens of bunting, so that with two or three speakers all talking at once on different subjects it was at times difficult to follow either one, especially with the occasional interruptions by the sounds of applause in adjacent rooms.

The opening meeting of the Congress was held in the main hall of the Coliseum, on Monday morning, Sept. 12; a joint meeting of the American Institute of Electrical Engineers and the Institution of Electrical Engineers (Great Britain) was held in the Festival Hall at the exhibition on Sept. 14; the closing meeting of the Congress was held in the Congress Hall, at the exhibition, on Sept. 17. The meetings of the several sections were held in rooms at the Coliseum, during the mornings of Sept. 12, 13, 15 and 16.

At the opening meeting, Mr. David R. Francis, President of the Exhibition, delivered an address of welcome; and Prof. Elihu Thomson, President of the Committee of Organization of the Congress, gave an outline of its development and its purposes. Other brief addresses were made by Mr. R. Kaye Gray (President of the British Institution of Electrical Engineers); Prof. M. Ascoli, President of the Italian Electrical Association, Mr. G. de Nerville, of France, and Prof. W. E. Goldsborough, Chief of the Department of Electricity of the Exhibition. The following permanent officers were elected: President, Prof. Elihu Thomson; Vice-Presidents, Bion J. Arnold, Prof. H. S. Carhart, Prof. W. E. Goldsborough, C. F. Scott and Dr. S. W. Stratton; Treasurer, W. D. Weaver; Secretary, Dr. A. E. Kennelly. The following foreign honorary Vice-Presidents were also elected: Dr. R. T. Glazebrook, Col. R. E. B. Crompton, Mr. R. Kaye Gray and Prof. John Perry (Great Britain); Prof. Moise Ascoli and Prof. L. Lombardi (Italy); Mr. Antonio Gonzales (Spain); Mr. Henri Poincare (France). Officers of the eight sections were elected, together with honorary officers from among the foreign members.

The government delegates held independent meetings as a "Chamber of Delegates," and discussed at some length the question of a uniform international unit of electrical measurement. No decision was reached, however, and the Congress adopted a resolution in favor of referring the matter to a special international commission composed of representatives of various governments.

SECTION A.—GENERAL THEORY.

In this section the most important proceedings related to the question of electrical units: "Systems of Electric Units," Prof Ascoli; "Absolute Value of E. M. F. of Clark and Weston Cells," Profs. Carhart and Patterson; and "The So-Called International Electrical Units," by Dr. Frank A. Wolff. Dr. Glazebrook explained the units adopted by the British Board of Trade, and the standard instruments designed by Lord Kelvin for the measurement of these units; while he considered the Weston cell somewhat superior to the Clark cell for practical reasons, he was not prepared to recommend the adoption of the former. Prof. Carhart and Prof. Webster thought that the legal units in this country and in Great Britain are so nearly alike that nothing is to be gained by any change at the present time, the difference in values being but 0.1%. Dr. Kennelly, however, pointed out that this percentage of difference cannot be neglected in voltmeters, as 0.1-volt has an appreciable effect on the life of an incandescent lamp, and on this contracts are based. Another paper relative to the same subject was by Prof. Howard T. Barnes, on "The Mechanical Equivalent of Heat Measured by

Electrical Means," in which he showed that this measurement clearly illustrates the uncertainty existing in the values of the electrical units.

SECTION B.—GENERAL APPLICATIONS.

A lengthy paper on "Alternating Current Motors" was presented by Prof. C. P. Steinmetz, discussing the characteristics of these motors, and being largely of a mathematical character. Col. R. E. Crompton presented a paper on "Standardization of Dynamo-Electric Machinery and Apparatus," which was a review of the work of the British committee appointed to deal with this matter. For low pressures they have adopted voltages of 110, 220, 440 and 500; it would have been more symmetrical to have 550 as the highest, but the Board of Trade has not sanctioned anything higher than 500. For high pressures it was found convenient to settle on the even figures of 2,000, 3,000, 6,000 and 10,000 volts at the primary terminals of the transformers, whereas those at the terminals of the generators were necessarily 10% higher. As to frequencies, a strong majority of the committee favored 50 cycles as the chief standard, with 25 cycles as a subsidiary frequency for uses where the lower frequency would be desirable.

Up to the present, a maximum temperature of 50° C. should not be exceeded in the hottest part of the coils (or 75° C. in a few cases when the work is intermittent); yet when more accurate methods of determining the temperatures of the hottest parts of the coils have been laid down, considerably higher temperatures may be allowed by our English committee when it issues its final test conditions, for many of the materials which are to-day used by the manufacturers for the insulation of coils and other portions of electrical machinery were actually subjected for periods up to nine months to a steady temperature of 150° C., without either electrical or mechanical deterioration. It has also been shown that the maximum temperature reached by the hottest part of the coils that are nowadays used can never reach a point more than 25° in excess of that of the average temperature of the coil obtained by percentage rise in the electrical resistance of the copper of the coil itself. It appears therefore that these materials may be exposed for great lengths of time to a temperature which, when measured by rise in electrical resistance, may be as high as 125° C., which corresponds to somewhat less than 150° C. at the hottest part of the coil.

A paper dealing with the subject considered in the above quotation was that by Prof. H. J. Ryan (Cornell University), on "Some Elements in the Design of High-Pressure Insulation," showing that in apparatus employing the higher electrical pressures in commercial use, great difficulty is encountered in the provision of insulation to withstand continuously the electric strains that are encountered. The air-insulated transformer is impracticable for pressures higher than about 35,000 volts; oil may be used successfully for the highest pressures desired in practice, but even with the most approved method of using oil the conditions are not ideal. The "rational solution" of the problem was suggested to be the use of metallic guards or envelopes closely surrounding the coils or sections of the circuits of such high-pressure apparatus. Prof. Harold B. Smith (Worcester Polytechnic Institute) read a short paper on "Experiments with Transformers of Very High Potentials," describing transformers built at the Institute for 150,000 volts (which was used for potentials as high as 190,000, and for 175,000 volts 10 hours a day for several days), 210,000 volts, and 500,000 volts. The latter is to be changed for a potential of not less than 750,000 volts effective (or over 1,000,000 volts maximum). A transformer of 200 KW., 300,000 volts, has also recently been completed.

Papers by Dr. Clayton H. Sharp on "The Equipment of a Commercial Testing Laboratory," and by Mr. Charles Day on "Electric Motors in Machine Shop Service," dealt with the practical application of electrical equipment, and the new problem of radio-activity was dealt with in a short paper by J. Elster and H. Geitel on "Natural Radio-Activity of the Atmosphere and the Earth."

SECTION C.—ELECTRO-CHEMISTRY.

Most of the papers in this section related to metallurgical work, but they included a paper on the new Edison storage battery. Mr. James Swinburne's paper on "Chlorine in Metallurgy" suggested a process for the use of chlorine in ore reduction. Prof. F. Haber and Dr. L. Bruner (Berlin Technical High School), had a joint paper on "The Carbon Cell," and Prof. G. A. Hulett (University of Michigan), had a paper on "The Materials Used in Standard Cells and Their Preparation."

SECTION D.—ELECTRIC POWER TRANSMISSION.

The first paper was a review of the electrical transmission plants in Switzerland, by Mr. E. Bignami, which was read by Dr. Louis Bell. Mr. F. G. Baum presented a paper on "High Potential, Long-Distance Transmission and Control," which dealt particularly with the system of the California Gas & Electric Co.; 70 miles at 50,000 volts, 70 miles at 40,000, and other lines at 23,000, 16,000, 10,000 and 5,000 volts. The longest transmission distance is 200 miles. The plant and methods of the Bay Counties Power Co. (controlled by the above mentioned company) were described in a paper by Mr. L. M. Hancock; and Mr. F. O. Blackwell read a paper on "Conductors for Long Spans," which was very similar to a former paper by him, printed in our issue of July 7. Other papers on the same line of work were "The High Tension Transformer in Long Distance Power Transmission," by J. S. Peck, and "The Construction and Insulation of High Tension Transmission Lines," by M. H. Gerry, Jr. A general review of American practice in the construction and operation of high-tension lines was presented by Dr. F. A. C. Perrine.

SECTION E.—ELECTRIC LIGHT AND DISTRIBUTION.

Here again the subject of insulation came up, being dealt with in a paper by Mr. E. Jona (Italy), on "Insulating Materials in High-Tension Cables," as well as a paper by Mr. Carl Roderbourg (Germany)) on "Electric Train Lighting on the Prussian State Railways." Three papers dealt with the metering of electric current: "Improvements in Electrolytic Meters," by Mr. Arthur Wright (England); "A Study of Integrating Electric Meters," by Mr. Carl D. Haskins; and "American Meter Practice," by Mr. George R. Green; this last was a lengthy paper describing instruments and methods in use. The integrating meters were classified by Mr. Haskins as follows: 1, Electrolytic; 2, thermal; 3, clock; 4, relay or controlled; 5, variable transmission; and 6, electrodynamic. There were also five papers on apparatus: 1, "Single-Phase Motors," Max Deri; this suggested a combination giving an externally excited, compensable induction motor; 2, "The Testing of Alternating Current Generators," by Mr. B. A. Behrend; 3, "Effect of the Steam Turbine on Central Station Practice," by W. L. R. Emmet; 4, "Storage Batteries as an Adjunct to Central Station Equipment," Mr. Gerhard Goettling; this outlined the methods of installation and operation as practiced by the Edison companies; 5, "Rotary Converters and Motor Generator Sets," by Mr. Wm. C. L. Eglin. This paper stated that in the distributing systems of the electric supply companies in this country the demand for low-tension direct current service is usually of the first importance.

In all cases the percentage of the total load converted from alternating current to direct current is large, so that an effective, reliable and efficient means of transforming alternating current to direct current is essential. The three methods available for this purpose are rotary converters, motor generator sets, and rectifiers. The first two only are available at present for transforming large currents.

Conclusions. The type of machine to be installed in sub-stations depends principally upon the frequency of the system and the importance of reliable and continuous service. In cases where the largest percentage of the output of the generating station is to be transformed to low-tension direct current, 25-cycle rotary converters should be installed on account of their higher efficiency and lower first cost. The very large number of these machines which are now in successful operation proves conclusively their reliability and effectiveness. In mixed systems, and where the percentage of current transformed for low-tension distribution is small, motor generators are desirable. With higher frequency, particularly 60 cycles, it has been shown that motor generators compare favorably in efficiency and are much more reliable and simple in their operation.

In relation to the distribution of current, Mr. Alex. Dow read a paper on "The Direct-Current Distributing Systems of American Cities;" Dr. Gotthold Stern had a paper on "The Superiority of Alternating Current for the Supply of Current to Large Cities," and Mr. George N. Eastman read a paper on "The Protection and Control of Large High-Tension Alternating Current Distribution Systems." An interesting paper on "Underground Electrical Construction" was read by Mr. Louis A. Ferguson (Chicago); this dealt particularly with the conduit system for cables, including the cost of construction for conduits and manholes. Office records of underground work, and methods of testing cables were also discussed.

SECTION F.—ELECTRIC TRANSPORTATION.

Probably the most notable paper in this section was the one by Mr. B. J. Arnold (Chicago) on "Early Work in Polyphase and Single-Phase Electric Traction," dealing particularly with his own system and apparatus, which have already been described in our columns. Several papers on motors were presented, including one by Dr. Steinmetz on "Alternating-Current Motors." Mr. Sprague's paper on "The History and Development of Electric Railways" traced this history from Davenport's toy motor (with primary battery) of 1834, and the first practical electric railway at Richmond, Va., in 1888, to the work of the Pennsylvania and New York Central railways in New York, the Valtellina Ry. (polyphase system) in Italy, and the high-speed line near Berlin, where electric cars have obtained a speed of 126 miles an hour. Mr. Sprague does not regard the electric motor as the rival of the steam locomotive:

Will it replace the steam locomotive? Perhaps the best answer is that "its future is not in the wholesale destruction of existing great systems. It is in the development of a field of its own, with recognized limitations but of vast possibilities. It will fill that field to the practical exclusion of all other methods of transmitting energy; it will operate all street railway systems, and elevated and underground roads; it will prove a valuable auxiliary to trunk systems; but it has not yet sounded the death-knell of the locomotive any more than the dynamo has that of the stationary steam engine. Each has its own legitimate field which will play its proper part in the needs of all civilization.

Prof. Rasch had a paper on "The Booster Machine in Traction Service," and a paper by Mr. R. A. Parke on "Braking High Speed Trains" was read by title. This latter dealt with high-speed electric service, and remarked upon the great attention given to acceleration and the neglect of the question of retardation. A paper by Mr. L. B. Stillwell described the Wilkes-Barre & Hazleton electric railway, which employs a protected third-rail system. Mr. Philip Dawson presented a paper on "The Electrification of English Railways," describing the work done on the London underground lines, the Mersey Tunnel Ry., the Liverpool & Southport Ry., and the suburban lines of the Northeastern Ry. Two other papers read by title were Mr. Ernest Danielson's "Theory of the Compensated Repulsion Motor," and Prof. Niethammer's "Alternating and Direct Current Traction." Both of these were largely analytical and mathematical.

Considerable time was given to the discussion of electric traction systems. Prof. Steinmetz said that with the exception of Mr. Arnold's system the single-phase induction motor is quite out of the question for railway work. Mr. F. J. Sprague thought that a single trolley wire is all that will be allowed and systems requiring a multiplicity of wires are out of the question. The direct-current motor has inherent advantages over the single-phase alternating motor, while the high-tension alternating current must always be a source of danger on the car. The electrification of terminal lines of the New York Central and Pennsylvania railways at New York was of necessity adopted under special conditions, and he repeated his opinion as quoted above to the effect that for trunk line service there is no probability of the steam locomotive being superseded. As to electric competition with steam roads, he thought that money spent in electrifying a steam road would be better expended in protecting the latter's territory by building or acquiring independent electric roads. Mr. Scott (England) referred to the new electric lines in England, and remarked that if any more people were killed by

the third-rail the public would probably demand that it be abandoned. He suggested a system with maximum speed limit, each road buying equipment for the desired speed, but this was generally regarded as utterly impracticable from an operating point of view. Mr. Ward Leonard described his system of control as applied to elevators and the turrets of warships, and thought this system would be well adapted for railway service, an opinion combated by Mr. Steinmetz. Both Mr. Leonard and Mr. Lamme (Pittsburg) referred to the investigations in connection with the proposed electric operation of railways in Sweden. Mr. Steinmetz referred to the number of systems now being brought forward, and Mr. B. J. Arnold remarked that the winning system will be the one with the greatest practical simplicity and lowest cost.

SECTION G.—ELECTRIC COMMUNICATION.

Three or four papers on wireless telegraphy were presented in this section, including one by Mr. De Forest (inventor of the De Forest system), and one by Prof. J. A. Fleming (London) on "The Present State of Wireless Telegraphy." As to the claims made concerning the inefficiency and uncertainty of this method of communication, especially for commercial purposes, Prof. Fleming pointed out the early troubles with telegrapny, and the failure of the first Atlantic cable in 1858, the next new cable not being laid until 1866.

Hundreds of wireless messages have already crossed the Atlantic, and in that one single fact we have the guarantee of subsequent achievement.

No one who was connected, in their early days, with the then new enterprises of incandescent electric lighting or urban telephony, and who can look back at what has been accomplished in 20 years from apparently the most unpromising beginnings, will need assurance that commercial success can always be obtained where there is a substantial scientific achievement at the bottom of it.

The other papers included two on the printing telegraph system: "Printing Telegraphy," by Dr. Louis M. Potts, and "Modern High-Speed Printing Telegraph Systems," by Mr. J. C. Barclay. A paper by Mr. Joseph Hollos dealt with "Simultaneous Telegraphy and Telephony," and Major Samuel Reber, U. S. A., presented a paper on "The Telegraph, Telephone and Cable in War." Mr. Kempster B. Miller discussed "The Automatic versus the Manual Telephone Exchange"; he did not mention the automatic system now in use in Chicago, but described other similar systems at Grand Rapids, Fall River and New Bedford. His conclusions were favorable to the automatic exchange system, not only in regard to its mechanical practicability and reliability, but also on account of the fact that "there are features of the automatic system which may make it so popular as to force upon the owners or prospective owners of telephone industries a serious consideration of the doctrine of expediency."

SECTION H.—ELECTROTHERAPEUTICS.

The papers in this section dealt mainly with the application of electricity to surgical work and medical work; the former includes the use of the X-ray in locating obstructions and studying fractures and dislocations, etc., the latter includes the use of the electric light and electric current in the treatment of diseases, destroying tumors and cancerous growths, etc. Dr. S. Shatzky had a paper on "The Action of the Constant Current on the Vitality of Microbes," showing the favorable effect of the current in inflammations by killing or weakening the harmful microbes. There was also a brief paper by Prof. John W. Langley (Case School of Applied Science) on "The Electrical Purification of Drinking Water." Attempts to destroy bacteria by the direct action of electric charges have not resulted in marked success; the most successful method of electrolysis for drinking water is by the use of aluminum plates as electrodes, and a plant of this kind is working commercially at Cleveland, O., where the action on the bacteria is very satisfactory.

THREE-HINGED STEEL ARCH TRUSSES FOR THE U. S. GOVERNMENT BUILDING; ST. LOUIS EXHIBITION.

In the article on the building construction of the St. Louis exhibition in our issue of May 19, 1904, reference was made to the fact that the only important steel structural work is in the United States Government building. The main structural framing of that building consists of steel arch trusses of the three-hinged type; the general design and some details are shown in the accompanying cuts, Figs. 1 and 2.

The span of the arches is 172 ft. c. to c. of pins, and their rise from heel pins to center pin is 65 ft. 9½ ins. The trusses are spaced 35 ft. apart, and are connected transversely by six lines of lattice girders, carrying the posts of the main roof and monitor roof, and by eight other intermediate transverse struts. A horizontal wind truss is located as indicated in Fig. 1. The assumed loading was as follows:

Dead Load: Roof, 10 lbs. per sq. ft. on slope; dome, 12 lbs. per sq. ft. of roof surface; side walls of dome and building, 15 lbs. per sq. ft of surface; trusses, 10 lbs. per sq. ft. of floor surface.

Wind Load: Side Walls, 20 lbs. per sq. ft.; dome, curved, 15 lbs. per sq. ft. of projection on vertical plane.

Snow Load: On roof of main building, 20 lbs. per sq. ft. horizontal; reduced to 10 lbs. per sq. ft. on ventilator over center.

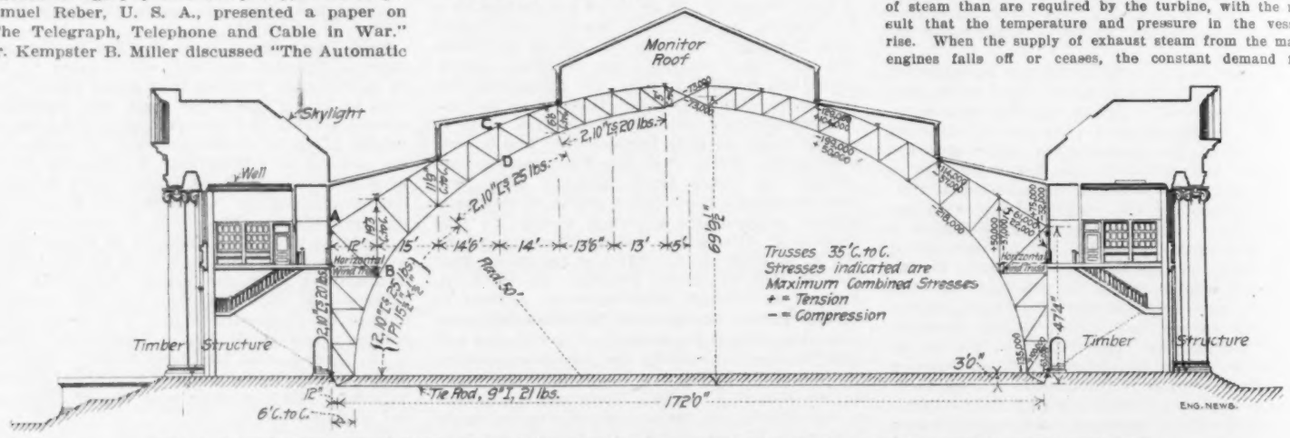


FIG. 1. GOVERNMENT BUILDING, ST. LOUIS EXHIBITION, SHOWING STEEL THREE-HINGED ARCH TRUSSES.

The revised estimate of loads for the 35-ft. bay figured out as follows, per square foot of horizontal projection:

	Lbs. per sq. ft.
Weight of steel	13.1
" " roof	6.6
" " tin covering	0.5
Actual total	20.2
Calculated total	21.5

The loading on one truss for the 35-ft. bay was:

	Actual. Lbs.	Estimated. Lbs.
Total dead load	40,500	70,000
Total steel	80,000	64,000
Grand total	120,500	134,000

The arches are built up of channels, plates and angles, and have 4½-in. shoe pins and 3-in. center pins. The shoe pins of each truss are connected by a tie-bar consisting of a line of 9-in. I-beams.

The building was designed by Mr. James Knox Taylor, Supervising Architect of the Treasury Department, Washington, D. C. The steel trusses were designed by Mr. F. L. Averill, Structural Engineer.

UTILIZATION OF EXHAUST STEAM IN LOW-PRESSURE STEAM TURBINES.*

By Leonce Battu.†

Improvements in steam engine practice during recent years, such as the use of high-pressure steam, multiple expansion, superheating and condensation, have effected great reductions in steam consumption, but there is one class of engines in which the steam consumption per HP. is still extremely large. This class is composed of those engines whose daily service consists principally of starts and stops, such as rolling mill engines, hoisting engines, elevator engines, etc. Trials of modern hoisting engines frequently show a steam consumption of 65 to 80 lbs. per HP.-hr., while 100 to 120 lbs. is not uncommon. Allowing 20% condensation in the cylinders and passages, such an engine will discharge into the atmosphere about 9,000 to 10,000 lbs. of steam per hour; this is totally lost, although theoretically capable of developing 500 to 600 HP., if supplied at atmospheric pressure and exhausted at a vacuum of 27 ins. Rolling mill engines frequently consume 50,000 lbs. of steam per hour, which is theoretically capable of developing 2,500 HP., as above.

Many inventors have turned their attention to devising means for reducing this enormous waste of energy. It has been proposed to utilize sulphur dioxide gas in an additional cylinder, but while theoretically resulting in a saving there are so many practical difficulties that its use cannot become general. By Mr. Rateau's system of directly utilizing the exhaust steam from intermittently-running engines for the production of power, a large amount of supplementary power can be obtained with a low first cost of plant. This system has been in successful operation in Europe for several years.

The principle of the process consists in the direct utilization of the exhaust steam from the main engines by means of low-pressure steam turbines, operated condensing; these latter drive electric generators, centrifugal fans and pumps, blast-furnace blowers, or other apparatus requiring constant rotary motion. The irregular exhaust (usually at or near atmospheric pressure) must be converted into a continuous supply at a practically constant pressure, and for this purpose a regenerative steam accumulator is used. This consists of a vessel containing substances suitable for performing the function of a fly-wheel for the heat in the steam. On entering this apparatus the steam is condensed, at or near atmospheric pressure, and its heat so accumulated during the periods when the main engines are exhausting larger quantities of steam than are required by the turbine, with the result that the temperature and pressure in the vessel rise. When the supply of exhaust steam from the main engines falls off or ceases, the constant demand for steam by the turbine reduces the pressure in the apparatus, and re-evaporation or regeneration of the steam takes place with consequent reduction of temperature. The heat absorbed by the "heat fly-wheel" in the first period is given out again during the second.

In practice the variations of temperature are about 6 to 10° F., which correspond to pressure variations of 2 to 3½ lbs. per sq. in. The range of pressure is entirely controlled by the weight of materials forming the "heat fly-wheel" and by adjusting the safety valve of the apparatus. The accumulator is built in four principal forms, depending on the materials forming the "heat fly-wheel": (1) Cast-iron pan, (2) scrap iron, (3) automatic agitation of water, (4) mechanical agitation of water.

(1) CAST-IRON PAN TYPE.—An apparatus of this form is employed at the Bruay mines in France. It consists of one or more sheet iron tanks usually placed vertically and containing shallow pans of cast iron. These pans are filled with water when the apparatus is first put in operation and the steam circulates between and around them. Part of the exhaust steam from the main engine passes directly down the walls of the tank and flows to

*Abstract of a paper read at the meeting of the Western Society of Engineers, Chicago, Sept. 21, 1904.

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...turbine; the remainder is condensed while the primary engine is exhausting and is re-evaporated when the exhaust stops.

(2) SCRAP IRON.—A simpler arrangement consists of a tank containing old scrap iron. A 600-HP. installation of this type is in operation in the Reunion mines of the Herrossa & Alicante Ry., Spain. In this apparatus the cast-iron pans are replaced by old rails. The tank can also be placed horizontally. In this type, however, the heat absorbing capacity of the water contained in the pans of the previous type is lost. However, where old rails are available, this form results in great economy in first cost. For this reason it was found best to adopt this type at the Reunion mines.

Water being the substance having the greatest capacity for heat, it is evidently desirable to use it as the "heat fly-wheel" to the exclusion of all other materials. But as water is a very bad conductor of heat, in order to communicate a large quantity of heat to a given mass of water in a short space of time it is necessary that the water be arranged in very thin sheets, or that an active circulation be produced in it so as to bring the whole mass rapidly in contact with the source of heat. The water types of accumulators have been designed to meet these requirements.

(3) AUTOMATIC AGITATION OF WATER.—The apparatus is formed of a horizontal cylindrical boiler nearly full of water. Several horizontal pipes of elliptic section and large area are arranged in the boiler or tank, and reach from end to end with vertical passages between them. The steam enters these pipes and passes into the passages by a number of small openings in the walls of the pipes. The steam in discharging through these openings into the passages causes an extremely rapid movement in the liquid which flows up one set of passages and descends in other passages between the pipes and the walls of the tank. The necessary energetic circulation of the water is thus obtained.

Sheet iron plates are arranged over the up-flow passages to direct the flow of the water in a horizontal direction and prevent its being thrown up into the dry pipe. The apparatus is furnished with a safety valve and discharge valve actuated by a float when the water rises to a given level. During the discharge of steam by the primary engine an energetic boiling of the liquid takes place. When the exhaust stops the water becomes more steady and gives back as steam the heat contained in it in a manner similar to an ordinary boiler. The dimensions of this apparatus are relatively moderate. An accumulator 20 ft. long and 6 ft. 6 ins. diameter, containing 10 tons of water, allows of the utilization of 10,000 lbs. of steam per hour, when the primary engine has stops of as much as, and not over, a minute. A 350-HP. accumulator of this type is under construction for the Bethune mines, Pas de Calais.

(4) MECHANICAL AGITATION OF WATER.—This active circulation of water can be obtained by means of mechanical power; for instance, a pump raising the water to the top of the accumulator, the discharge pipe flowing in a perforated tank, through which perforation the water comes back to its balance.

The weight of materials necessary to the regeneration of steam increases in proportion to the quantity of steam per hour and the duration of the stops. Suppose, for instance, it is desired to construct an accumulator of the water type. During each stoppage of the primary engine the accumulator must give up a weight of steam equal to

$$P = \frac{Q\,t}{3{,}600}$$

Q being the weight of steam per hour and t the duration of each stoppage expressed in seconds.

These P pounds of steam contain at atmospheric pressure 966 B. T. U. per lb. Whence the accumulator must be figured to be capable of giving up P × 966 = N units within the allowable limits of variation of pressure.

Calling θ the variation of temperature corresponding to these pressure limits existing between the commencement and end of each period of rest, and if X be the required weight of water forming the "heat fly-wheel," we have (the specific heat of water being unity)

$$X = \frac{N}{\theta} = 966\,\frac{P}{\theta}$$

If, in place of water the "heat fly-wheel" is composed of cast-iron, of which the specific heat is about 0.11, a mass of iron will be required nine times as great as we have obtained above. For example, the steam consumption of the secondary engine being 2,200 lbs. per hour (corresponding to about 77 effective HP.), the duration of each stop being one minute and the allowable range of temperature 10° F., then we have

$$P = \frac{2{,}200 \times 60}{3{,}600} = 36.6$$

and the accumulator must deliver

$$36.6 \times 966 = 35{,}400 \text{ B. T. U.}$$

Whence, the weight of water necessary to deliver this quantity of heat per minute, with a range of temperature of 10° F. is

$$\frac{35{,}400}{10} = 3{,}540 \text{ lbs., or about } 1.5 \text{ tons.}$$

For cast-iron, a weight of

$$\frac{1.5}{0.11} = 13.75 \text{ tons.}$$

The steam accumulator is provided with the following fittings and accessories which make the main engine and the turbine independent of each other: (1) A free air relief valve to allow surplus exhaust steam, not required by the turbine, to pass to the atmosphere or to the condenser. (2) An automatic expansion valve admitting live steam to the turbine if it requires more steam than is supplied by the exhaust, or if the main engine is shut down; these two valves enable the engine and the turbine to be operated independently. (3) A steam check valve to shut off the accumulator from the turbine when the latter is using live steam alone. (4) A water check valve (for the water type of accumulators only) to prevent the water from returning to the main engine when it is shut down. (5) An automatic trap to discharge water entrained in the exhaust steam.

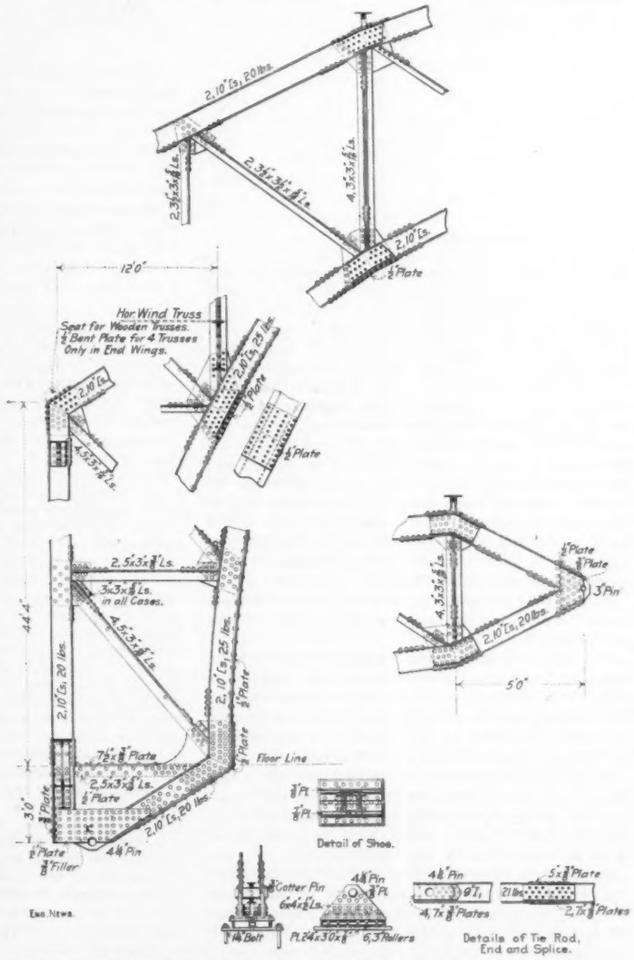


FIG. 2. SOME DETAILS OF THREE-HINGED ARCH TRUSSES, U. S. GOVERNMENT BUILDING.

It is possible to utilize the regulated flow of steam in a reciprocating engine, but such an engine would be of very large size and high cost, while its thermal efficiency would be low on account of the great cylinder condensation that would result. It is unimportant what system of turbine is employed. The Rateau turbine* is of the multi-cellular direct-action type, composed of light sheet-steel wheels carrying circular buckets and revolving between circular diaphragms which carry the guide blades and are set in grooves in the turbine casing. The steam consumption of this turbine is very low, being only 31.5 lbs. of steam per brake HP. under conditions where a reciprocating engine would require 50 lbs. (initial pressure that of the atmosphere and back pressure equivalent to 27 ins. of vacuum).

In the plant at Bruay,† already mentioned, the low-pressure turbine drives two dynamos supplying a three-wire system (500 volts). With low-pressure turbines, the more perfect the vacuum the better will the steam be utilized. In the Bruay plant the combined efficiency is 58% at 1,800 revolutions, but rises to over 60% when the speed is increased to about 2,000 revolutions per minute. Tests made in November, 1903, after 15 months' operation, showed no falling off in the combined efficiencies. When exhaust steam at atmospheric pressure is used, an electric HP. can be produced at the terminals of the dynamo for 26.5 to 36.3 lbs. of steam, depending upon the vacuum; with steam at 7.5 lbs. absolute pressure 1 HP. (electric) can be given with 36 lbs. of steam under good vacuum conditions. A sensitive governor controls the speed of the turbine, so that the variations do not exceed 1%, notwithstanding the fluctuations of pressure in the accumulator and of the load on the dynamos.

When the low-pressure turbine is supplied with live steam the steam consumption will evidently be increased above that of a machine working at full boiler pressure, and this will be important if the turbine is run in this way for long periods. For such cases a high-pressure section is added to the turbine to receive the live steam when the main engine is shut down. After passing through this high-pressure section the steam enters the low-pressure turbine. In this way the machine has equal economy whether run with exhaust steam, live steam or both in combination.

In some cases the exhaust from several engines can be delivered to a central station where it can be used in a number of turbines. Where a central condensing system is already installed, the accumulator and turbine are placed between the engine and the condenser. The accumulator can also be used without a turbine to steady the discharge of steam to the condenser. The reason that steam can be utilized better by the Rateau system than by operating the main engine condensing, is due to the fact that in a turbine the steam can be expanded down to the last limit and the turbine will give a high efficiency. The economies in the system are in low initial cost and cost of operaton.

Some of the plants now in operation or in course of construction are as follows: Donetz steel works, Russia, 2,700 HP.; Rombach steel works, Germany, 750 HP.; Poengsgen steel works, Germany, 700 HP.; Houssu mines, Belgium, 600 HP.; Firminy mines, France, 500 HP.; Bruay mines, France, 350 HP.

COPPER SULPHATE TREATMENT OF LAKES CLIFTON AND MONTEBELLO, BALTIMORE WATER-WORKS.

By Alfred M. Quick.‡

Montebello and Clifton are two low service storage reservoirs in the city of Baltimore which are supplied by gravity from Loch Raven, an impounding reservoir on the Gunpowder River, about seven miles from the city. The storage capacity of Lake Montebello when full is about 500,000,000 gallons, and of Lake Clifton when full about 235,000,000 gallons. Under normal conditions when these reservoirs are full, or nearly so, and when the water in the impounding reservoir, Loch Raven, is clear, about 50,000,000 gallons a day is run into and drawn out of these reservoirs.

When the water in Loch Raven is muddy it is shut off and these two reservoirs are drawn down by the consumption. Consequently the water in them is always quite clear, and such complaints of bad water as there have been in the past from consumers fed from them have been presumed to be caused by the stirring up of some old sediment in the mains, or the sucking into circulation of some stagnant water in dead ends in the system.

Although we had always supposed that there

*Engineering News, June 9, 1904; pp. 544 and 553.
†Engineering News, June 9, 1904; p. 547.
‡Water Engineer, Baltimore, Md.

TABLE I.—Copper Sulphate Test, Lake Clifton, Baltimore Water-Works, July 29, 1904.

Contents of lake at time of test, 230,000,000 gallons. Depth of water, 26 ft. Area of water surface, 29 acres.
Temp. of air, 92°. Temp. of water, 78°. Time required to dissolve sulphate, 130 min.
Amount of sulphate used, 300 lbs. = 1 part in 6,390,000, by weight.

	No. of algae per cu. cm.					
	Before applying.	After applying sulphate.				
Date	July 28	July 30	July 31	Aug. 1	Aug. 2	Aug. 3
Hours after application	.....	24	48	72	96	120
Odor	None	None	None	None	None	None
Color	Clear	Clear	Clear	Clear	Clear	Clear
Alkalinity	.....	Faint	Slight	Slight	Slight	Slight
Diatomaceae:						
Stephanodiscus	1	.....	.....	.....	.....	.....
Tabellaria	.....	2	.....	.....	.....	.....
Synedra	2	2	.....	.....	.....	.....
Cyclotella	2	.....	.....	.....	.....	.....
Chlorophyceae:						
Sorastrum	.....	.....	.....	.....	1	.....
Eurodina	3	1	3	.....	.....	.....
Conferva	.....	1	.....	1	2	.....
Pandorina	1	1	.....	.....	.....	.....
Protococcus	.....	9	3	5	7	1
Scenedismus	2	2	.....	.....	1	.....
Botryococcus	5	.....	.....	7	1	.....
Coelastrum	.....	.....	.....	3	.....	.....
Cosmarium	7	.....	.....	.....	.....	.....
Ulothrix	41	.....	.....	.....	.....	.....
Sphaerozosma	2	.....	.....	.....	.....	.....
Unknown	.....	.....	1	.....	.....	.....
Leptothrix	.....	28	8	5	.....	1
Cyanophyceae Chroococcus	3	3	.....	.....	.....	.....
Total algae, per c. c.	69	49	15	21	12	2
Bacteria per c. c.	480	.....	.....	.....	.....	*3,000
Colon bacillus	Present in 1 and 50 c.c	.....	.....	.....	.....	none

*Increase in bacteria probably caused by rain after application.

was some microscopic vegetable growth in Montebello and Clifton it had never made itself manifest there previous to this year, either by any considerable amount of scum or by any pronounced odor.

Late in the spring of this year, however, complaints were received from some ice manufacturing companies that there was something in the water which was causing a cloudy greenish discoloration of the ice and forming a green scum in the freezing tanks. At the same time there was a perceptible odor from the water in one of the reservoirs.

Consequently we determined to take the matter up with Mr. Moore of the Agricultural Department at Washington. He sent Mr. Kellerman, his assistant, to Baltimore, who made a personal examination of the lakes and analyzed samples of the water. These analyses showed that numbers of algae were present in the water, including many of the particular species that cause the worst odors. Mr. Kellerman advised that the lakes be treated with the copper sulphate, suggesting both the method of application and the quantity to be used in each lake.

For Lake Clifton 300 lbs. of sulphate was used, or about 1 part to 6,390,000 by weight. The method of application was as follows: The lake was first shut off entirely both at the inlet and outlet. The sulphate was in four bags of 75 lbs. each. One bag at a time was suspended from the stern of a rowboat, and as soon as it was about three-quarters dissolved another bag was put out. The boat was rowed around the lake in concentric courses about 40 or 50 ft. apart, and at such a rate as to completely cover the lake by the time the four bags of sulphate were dissolved. It took 128 minutes to dissolve the 300 lbs. applied. A sample of the water was taken near the center of the lake just previous to the application of the sulphate, and samples were taken at the same place in the lake at intervals of 24 hours after the application. These samples were for biological analyses. Samples of the lake water were also taken in sterilized bottles, both before and after application of the sulphate, for bacteriological analyses.

The results of these analyses are shown by Table I. It will be noted that the analyses indicate a very great reduction in the number of algae in the first 48 hours after treatment, and practically a complete elimination of the algae in 120 hours. On account of rain falling in the reservoir during treatment, unfortunately the bacteriological analyses give no correct indication of the action of the sulphate on the bacteria in the lake. These analyses were all made by Dr. Wm. R. Stokes, the city bacteriologist. An analysis of the samples was also made by the city chemist to determine the proportion of copper present, and no trace of copper was found in the water as early as 24 hours after application of the sulphate.

The method of treatment of Lake Montebello was exactly the same as at Lake Clifton, except that a larger amount of copper sulphate was used. The amount applied was 600 lbs., or about 1 part in 6,685,800 by weight. As with Lake Clifton, the analyses showed a very considerable reduction in the number of algae in 48 hours after application of the sulphate, but the analyses of samples taken at intervals of 24 hours thereafter showed a slight increase in the number of algae until the eighth day after treatment, when the number per cubic centimeter dropped to 14. At that time it was found necessary to turn Lake Montebello into consumption, and therefore no further analyses were made. It is possible that if the examination had been continued we would have found the algae practically eliminated, the same as at Lake Clifton. The details of these analyses are shown by Table II.

A chemical analysis showed no trace of copper in the water five days after application of the sulphate.

We had no bacteriological analyses made of the water in Lake Montebello because our experience with Lake Clifton tended to substantiate the intimation by Mr. Moore that the proportion of copper sulphate which we used would be too weak to have much if any effect in reducing bacteria.

So much for the results shown by analysis. The practical value of the treatment was observed in the very great diminution in the number of complaints of bad water, which had been unusually large just previous to the experiment.

In order to determine how lasting the effect of the sulphate would be in reservoirs into and out of which such a large proportion of their capacity is run every day, and also to see whether a supplementary treatment would be necessary, we had samples taken for analysis from both lakes on Sept. 7th. This was about four weeks after the treatment of Lake Montebello and about two weeks after the treatment of Lake Clifton. These analyses showed the following results:

	Number of algae per cu. cm.	
	Clifton.	Montebello.
Schizomycetes:		
Leptothrix	39	3
Diatomyacae:		
Navicula gracilis	2	
Asterionella	1	1
Stephanodiscus	1	..
Chlorophyceae:		
Protococcus Wimmeri	14	56
Protococcus Viridis	2	3
Microsterias	1	..
Botryococcus	1	3
Arthrodesmus	..	1
Sorastrum	..	1
Staurastrum	..	1
	61	67

As these analyses showed the number of algae in the lakes to be nearly as great or greater than before the application of the sulphate, we submitted a copy of them, together with all the previous analyses, to Mr. Moore for his opinion as to the ultimate value of the treatment, and for his suggestions as to further experiments.

His conclusions in regard to the results of the experiment are more authoritative than any that we might draw, and consequently more valuable to those who may be interested in the subject. I therefore give his letter in full.

Washington, D. C., Sept. 12, 1904.

Mr. Alfred M. Quick,
Engineer Water Department, Baltimore, Md.

Dear Sir: I thank you very much for your letter of Sept. 10, together with the tabulated statement of the result of the treatment of Lake Montebello, as well as a copy of Doctor Stokes's letter.

According to Doctor Stokes's last report, it seems to me that the treatment has been as satisfactory as could possibly be expected. The organisms which now are present in the reservoir are among those which have shown themselves particularly resistant to the copper treatment, and I doubt if any of them will increase sufficiently to cause any trouble.

The only sample of Baltimore water which I have seen was the one Mr. Kellerman obtained from Lake Clifton, and this at the time of treatment must have contained seven or eight hundred filaments of *Anabaena circinalis*. I think this was undoubtedly the organism which was causing trouble at the time, and as there seems to be no trace of it at present in the water, it must have been thoroughly eradicated, as the weather we have had recently is calculated to make it increase very rapidly. From the reports received, it would hardly seem necessary that any additional treatment be given either to Lake Clifton or Lake Montebello. The number of organisms shown by Doctor Stokes's report to be present in these two supplies is very low, and unless they increase materially within a short time there could be no point to adding more copper sulphate. When the original treatment was recommended it was thought that possibly a second application per million would be necessary, and experience in other places has shown that a second mild treatment of this character sometimes results in the complete eradication of certain troublesome blue-greens which do not entirely go out on the first treatment. However, as I

TABLE II.—Copper Sulphate Test, Lake Montebello, Baltimore Water-Works, Aug. 8, 1904.

Contents of lake at time of test, 481,378,000 gallons. Depth of water, 30 ft. Area of water surface, 59 acres.
Temp. of air, 72°. Temp. of water, 76°. Dissolving time, 128 min.
Amount of sulphate used, 600 lbs. = 1 part in 6,685,800, by weight.

	No. of algae per cu. cm.								
	Before applying.	After applying sulphate.							
Date	Aug. 8	Aug. 9	Aug. 10	Aug. 11	Aug. 12	Aug. 13	Aug. 14	Aug. 15	Aug. 16
Hours after application	.....	24	48	72	96	120	144	168	192
Odor	None	None	Clear	None	None	None	None	None	None
Color	Slightly Opalescent	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Alkalinity	Slight	Slight	Slight	Slight	Slight	.....	.....	.....	Slight
Reaction	.....	.....	.....	.....	.....	Neutral	Neutral	Neutral	.....
Diatomaceae:									
Diatoma vulgare	.....	.....	.....	.....	.....	.....	2	1	.....
Navicula gracilus	3	3	2	2	.....	.....	.....	.....	2
Cyanophyceae:									
Anabaena flos-aquae	.....	.....	.....	.....	.....	1	.....	.....	.....
Chroococcus	3	.....	1	.....	1	1	.....	.....	3
Microcystis	1	.....	.....	.....	.....	.....	.....	.....	.....
Schizomycetes:									
Leptothrix	3	4	2	.....	1	.....	.....	.....	.....
Chlorophyceae:									
Protococcus	25	17	9	4	9	9	13	10	4
Scenedesmus	2	2	1	2	.....	3	3	1	3
Conferva	1	2	.....	2	2	.....	.....	.....	.....
Cosmarium	2	1	.....	1	1	1	.....	.....	1
Coelastrum	1	.....	.....	.....	.....	1	.....	1	.....
Botryococcus	2	.....	1	6	3	3	.....	2	1
Raphidium	1	1	.....	.....	2	.....	4	4	.....
Gentium	.....	.....	2	.....	.....	3	2	1	.....
Pandorina	.....	.....	.....	.....	.....	1	2	1	.....
Arthrodesmus	.....	.....	.....	.....	.....	.....	1	.....	.....
Unknown	.....	.....	.....	.....	1	.....	.....	.....	.....
Drapernaldia Ravenelli	.....	.....	.....	.....	.....	1	.....	.....	.....
Saccharomyces Cerevisiae	.....	.....	.....	.....	.....	2	.....	.....	.....
Distomaceae Distoma vulgare	.....	.....	.....	.....	.....	1	.....	.....	.....
Total algae	44	30	18	17	20	27	47	21	14

have said, judging from the reports, such a treatment by you would appear to be superfluous, and I hope you will be able to get through the present season without any increased algal growth in the reservoirs. I am,

Yours very truly, George T. Moore,
Physiologist and Algologist.

Up to Sept. 21 there have been practically no complaints of bad water in the city; and I should say that the weather conditions have been such as to favor the algae causing trouble if the particular species which do cause the trouble were present in the reservoirs to any considerable extent. In this connection I have the following additional statement from Professor Moore, made after I received the letter printed above:

The form of algae which your report shows are now present in these waters are particularly resistant to the action of copper sulphate, and on account of the removal of the large number of other forms and the addition of a considerable amount of organic matter, genera like Scenedesmus and similar unicellular forms are apt to increase in considerable quantities. Of course, if the genera which follows the removal of the objectionable species like Anabaena were likely to produce bad odors or tastes, it might complicate the treatment very much, but in no case have these secondary forms ever been the cause of any trouble, and it has been our experience that they ultimately disappear not to return.

THROUGH THE LAKE SUPERIOR IRON AND COPPER MINES WITH THE AMERICAN INSTITUTE OF MINING ENGINEERS.

I.

For many years it has been a happy custom of the American Institute of Mining Engineers to lay off work once a year and visit one of the mining or metal working districts of the United States, or, more rarely, of one of its neighbors to the north or south. Thanks partly to good management, but chiefly to the almost unlimited choice of destination, this is one of those customs that does not stale with age. This year it was elected to visit the iron and copper mines of Lake Superior. To those who made this trip, its success needs no proclamation. To those who failed to make it, no written account can supply the pleasure they have missed. Starting from Buffalo, the sail through the lakes, following the path of the great ore carriers from Duluth, was alone worth all the cost in time and money. Besides all its delights in sun and wind and sparkling water, this preliminary voyage served the very practical purpose of impressing upon all the commercial magnitude of the great inland waterway of North America as no statistical statement of commerce and traffic possibly could. Figures of the Lake Superior ore traffic are to be had in volumes, and some of them are astounding in their magnitude, but it may be doubted if they can in the most fertile imagination approach the impression conveyed by the endless procession of ships, deep loaded, grimy and ugly, plowing their way steadily past, two, four, six, and even ten, in sight at once from the decks of the excursion steamer.

Attention may well be given for a moment to this traffic which we are to trace to its source. If we were to represent each unit bulk of ore, say, each million tons, shipped from Lake Superior mines, by a thread line drawn from its source to its destination, we should find all but a few of these threads combining into one strand in the Detroit River, and taking the figures of 1902, we should find that this strand was composed of 22 threads. Tracing these threads to their source, we should find that thirteen of them led to the ports of Duluth, Superior and Two Harbors at the head of Lake Superior; that four led to Ashland, Wisconsin; that one led to Marquette and two to the Lake Michigan ports of Escanaba and Gladstone. At the mouth of the Detroit River the strand begins to separate, and we find three of its important threads stretching to Buffalo, two to Erie, four to Conneaut, four to Ashtabula, four to Cleveland and one each to Toledo, Lorain, and Fairport, and two splitting up to reach the minor Lake Erie ports. Of course, this graphical division is only a rough one, but if the interested reader will only lay it down on the map, he will have a better picture of the Great Lakes' ore traffic than can be given by many columns of figures.

The vessels which carry this traffic are of peculiar types and are of all ages, some wooden, some of steel, some self-propelling and some designed to be towed. The modern vessels are of steel and self-propelling, and by good fortune those of the party who were curious enough to make a Sunday trip, were able to inspect the very largest one that has yet been built, the "Augustus B. Wolvin," of 10,300 tons capacity. As indicating the dispatch with which these lake ore carriers are loaded and unloaded, the following figures will be of interest. On Aug. 5 the "Augustus B. Wolvin" was loaded from the Great Northern docks at Allouez in the following schedule:

Boat arrived at dock	2.45 p. m.
Started to load	4.16 p. m.
Finished loading, 9,000 tons	4.50 p. m.
Shifted, to complete cargo	45 mins.
Loading completed (10,245 tons)	5.45 p. m.
Total time at dock	3 hours
Total time loading	1 hr. 29 mins.

This cargo was unloaded at Conneaut, O., in 4½ hours. These are doubtless record figures, and general practice is far from approaching them, day in and day out. Indeed, the only loading witnessed by the writer was much slower than he had inmagined it would be, and certainly would not account for a cargo of 5,000 tons in much less than eight or nine hours. This opinion seems to be confirmed by figures given out by the Local Committee programme furnished the members at Duluth, which state that the average time of loading 1,000 tons of ore at the Duluth, Mesabi & Northern R. R. docks at Duluth in 1903 was 1 hour and 33 minutes. The average tonnage of vessels loaded at these docks in 1903 was 5,668. Time and statistics are not, however, available for analyzing the Lake Superior ore traffic, even had it not already been done time and again, and we will hasten to the immediate object of outlining the story of the Institute excursion.

THE SAIL THROUGH THE LAKES.

The Mining Engineers' excursion of 1904 started from Buffalo, N. Y., by way of the Northern Steamship Line, and the voyage was made by 76 members and guests and on the steamer "Northwest." Owing to the late evening start, but little was seen of works of interest at the sailing point. The new breakwater and a glimpse of the Lackawanna steel plant were afforded to the few who remained on deck, and then darkness prevented all further sight-seeing until morning. This gave the members an opportunity to greet old acquaintances and to meet new ones, the latter a somewhat more particular pleasure than usual, owing to the visiting foreign members from Germany and Russia. These turned out to be an unusually talented and companionable group of men, and, it is but just to say, added in large measure to both the jollity and the instruction of the excursion.

At Cleveland the excursionists got their first hint of the great ore traffic of which they were to see such remarkable evidences as the voyage progressed. Hardly had the vessel been moored, when a rumble and crash of sound drove the breakfasting members to the deck and the sluggards to the stateroom windows to see one of Cleveland's coal loading plants charging a large ore steamer for her return trip. As if knowing its expert audience, the crew seemed to put on extra speed, and the giant hoist raised car after car of coal, almost as fast as a man would empty buckets of water into a barrel, and poured their 25 and 50 ton cargoes into the vessel's hatches. A brief 20 minutes, however, was all that was allowed for sight-seeing at the docks, and then the steamer swung out into the lake and out of sight of land. The day was a beautiful one, and but for an occasional low-lying ore steamer on the horizon, there was little to distract the excursionists from their enjoyment of the glorious air and sunshine until late afternoon when the approach to Dertoit brought land in sight and, most interesting of all, gave those on deck their first real sight of the great procession of vessels coming from the mines and forests of the north. The vessel slowed to half-speed and then to almost snail's pace as the channel narrowed and the frequent craft passing within speaking distance, rendered cautious navigation imperative. Those who are fond of comparing water navigation by canal with the cheapness and ease of open lake sailing, need only to drag a few slow hours through the Detroit and St. Mary's Rivers after the clear open runs of Lake Erie and Lake Huron, to see where the difference comes in. The stop at Detroit was brief and uninteresting, but the succeeding hours sail was unsurpassed by any hour of the voyage for the quiet charm of the scenery. Here occurred the only storm of the trip, a gusty shower that struggled with the sunshine and spread a rainbow across the sky. Bedtime saw the boat in Lake Huron and the morning showed no land in sight, and brought a brisk, cold wind that sent the excursionists scrambling for coats and sweaters. A smudge of black against the meeting line of blue sky and green water showed here and there where a freighter was passing, but it was not until late afternoon after the steamer had left Mackinac and entered the St. Mary's River, that the procession of vessels from the north was again brought into full sight. At Sault Ste. Marie there was another stop, and unfortunately darkness had set in before the locks were entered and the vessel had been lifted to the upper level, so that the process of "locking through" was not seen by many. But the most interesting sight by far to the few who had last seen the Soo ten years ago, was the wonderful industrial development visible on every hand. The readers of Engineering News have been made familiar with the work that Clergue and his associates have done for the "Soo," and we need not report the details. To those, however, who remember the country villages of a decade ago, notable only because they were the location of the Government canals and locks, the present bustling cities with their electric lights and railways and their numerous power plants and manufacturing establishments, were a veritable revelation. The morning of the third day saw the steamer in the Portage canal, and sight was had of Houghton and Hancock and their surrounding hills of copper-bearing ore. Another day of sunshine and blue sky brought the voyagers to Duluth, where a hospitable welcome gave a fitting sequel to one of the most pleasant voyages ever enjoyed by the Institute members in all their years of continent-wide pilgrimages.

DULUTH MEETINGS.

Duluth is now the greatest iron ore shipping port of the world; its dream, which it proclaims from the housetops, is to become the greatest iron manufacturing center of the world. The visitors were told these things in many words as they assembled in the hall of the Commercial Club for their first meeting. The business of the meeting itself consisted merely of the presentation by title of some 28 papers and 17 formal discussions of papers and the reading in abstract of the obituaries of Prof. Wm. H. Pettee and C. Le Neve Foster, and of papers on "Centrifugal Ventilators" and "The Case of Henry Cort" by R. V. Norris and Charles Morgan. Mr. Norris's paper was an account of experiments on centrifugal ventilating fans, and Mr. Morgan paid a just tribute to the work of that pioneer English ironmaster whose labors received such scurvy recompense from his contemporaries. The afternoon was devoted to a boat excursion in Duluth and Superior harbors, visiting the harbor work of the U. S. Engineers and the new ferry bridge across the inlet. These works have been fully described and illustrated in Engineering News and need not be considered further except to remark that the towers of the ferry bridge are now nearly erected and work is progressing on the connecting span. In the evening there was a reception at the Northland Country Club.

At the second session the papers of David Baker on "Improvements in the Mechanical Charging of the Modern Blast Furnace," and of T. F. Witherbee on "Special Forms of Blast Furnace Charging Apparatus," were read in abstract. Mr. Witherbee's paper described and illustrated a number of blast furnace charging devices, and stated briefly the results of experience with them, and Mr. Baker described a series of experiments made by him with models to determine the distribution of ore with different forms of bells and furnace head equipment. These papers were briefly discussed by Messrs. Fackenthal, Croxton, Kennedy and Osann. The afternoon was devoted to a visit to the new Zenith furnaces at Duluth.

THE ZENITH FURNACE.

It has long been the dream of Duluth enthusiasts that sometime the center of the iron trade would be located at the head of Lake Superior. As a result of this dream, numerous plants have been projected and one or two have been

built, but all have failed. The reasons for this are several. There was first no great market for iron in the Northwest; second, there was no coke available at practicable prices, and, finally, there has been mismanagement and lack of money. The new Zenith furnace claims to have overcome all these difficulties, and time only can tell definitely whether or not its claim is justified.

The works were started about a year ago by the purchase of the old furnace at Duluth, and up to date about $1,000,000 have been spent in additions and improvements. As remodeled, the works now comprise a coal and stone dock 300 ft. wide and 1,200 ft. long, a 250-ton blast furnace with its necessary stoves and blowing engines, a 50-oven Otto-Hoffman coke making plant and adequate coal and ore handling plant. At present the furnace output is about 180 tons of iron daily. The coke plant has a capacity of 300 tons daily output of coke, 4,000 gallons of tar and 10,000 lbs. concentrated ammonia 20% NH_3. The coke gas amounts to 1,250,000 ft. daily, and it is used for illumination in Duluth and Superior. A supplementary water gas plant of 2,000,000 cu. ft. capacity is provided for times when the furnace is idle. It is the purpose of the company to extend the use of its gas for heating and power, and by means of subsidiary companies, to develop the manufacture of tar paper and other articles by which its output of tar will be consumed locally. The enterprise is a bold one, and Duluth people are watching its outcome anxiously as upon its success depends to a great extent the prospect for future iron manufacture at the head of Lake Superior.

A DRILL HOLE REAMER.

The accompanying illustrations, Figs. 1 and 2, shows a reamer for enlarging blast holes in rocks of such moderate hardness as the shales and sandstones of the Pennsylvania coal measures.

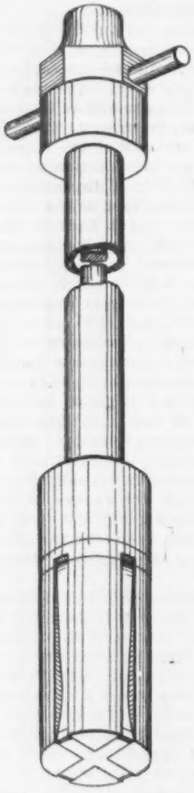


Fig. 1. A Tool for Chambering the Bottom of Drill Holes.

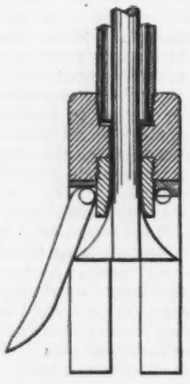


Fig. 2. Details of Reamer.

Instead of "springing" the holes with dynamite, the reamer is shoved into the hole, and upon turning the handle the cutters of the reamer are caused to "expand" until they engage the sides of the drill hole; then the upper end of the rod is hammered, thereby driving the ends of the cutters into the rock. As the cutters advance in the hole, the handle is rotated so that when the bottom of the hole is reached the cutters are fully expanded. The tool is then withdrawn and rotated sufficiently to cut a new channel in the manner just described. The chips are cleaned from the hole as from a drill hole in drilling. The tool can be used with a steam or air drill, which churns it up and down in the hole, at the same time that the cutters are being expanded by hand. The expanded holes in the illustration were 18 ins. long, made in very hard, close grained sandstone, expanding from 1¾ ins. to 4 ins., and the time consumed in reaming each hole by hand was 10 minutes.

By the use of this tool the cost of dynamite for springing holes is saved, but in tunneling or mining there is the even more important advantage gained in being able to enlarge a hole without vitiating the air with dynamite fumes. The advantage of having all the powder at the bottom of the drill hole is well known, but the delays in springing by successive shots and the further delays due to dynamite gases have often led to "straight shots," even though they were less satisfactory and more expensive in the matter of powder.

The wear on the reamers is said to be slight. In underground blasting wherever a reamer will operate with any degree of satisfaction, it is obvious that a reamer should be used wherever reduction in the powder bill is an object of importance; and, without doubt, there are many places where a reamer can be used to advantage in open cut work also.

The reamer illustrated in this article was patented April 5, 1904, by E. Cornelius, and is manufactured by the Cyclone Drilling Machine Co., of Orrville, Ohio.

COAL TESTING PLANT AT THE ST. LOUIS EXHIBITION.

A very complete plant for the testing of bituminous and anthracite coal, lignite, and coal-dust briquettes, has been installed at the St. Louis Exhibition by the U. S. Geological Survey, under a special appropriation from Congress of $60,000. Its operation is in charge of a committee consisting of Prof. J. A. Holmes, Chief of the Department of Mining and Metallurgy; Mr. M. R. Campbell, geologist; and Mr. E. W. Parker, statistician. For the following information concerning this plant, we are indebted to Mr. Parker. The boiler house and chemical laboratory operations are in charge, respectively, of Prof. L. P. Breckenridge, University of Illinois; and Prof. N. W. Lord, Ohio State University.

When any particular coal is to be tested, samples will be taken in the mine and also from the car delivered at the plant, and these will be analyzed separately. The coal will be burned under two Heine boilers of 250 HP., each boiler being run for a week at a time. The boilers have been calibrated, and equipped with apparatus for sampling the flue gases and taking temperatures at different parts of the furnace. The steam will be utilized in an Allis-Corliss engine of 250 HP., belted to a Bullock generator; this allows the determination of the electric horse-power produced from a given amount of coal. At the same time, some of the coal will be used in a Taylor gas producer plant, the gas being stored in a tank of 5,000 cu. ft. capacity. Samples of the gas will be analyzed, and the calorific value tested by a Junker calorimeter. This gas will be used in a Westinghouse gas engine of 250 HP. belted to a Westinghouse generator, so that the power obtained from coal in this way can be determined, for comparison with the power obtained by burning it under the boiler.

There are two briquetting plants each with an output capacity of 50 tons daily. One is of the Chisholm, Boyd & White type, built for the American Compressed Fuel Co., of Chicago; the other was built by Wm. Johnson & Sons, of Leeds, England. An endeavor will be made to find the kind of binder best adapted to different kinds of coal, and the briquettes will be burned under the Heine boilers.

Much of the coal will have to be washed before being subjected to the coking test; and for this purpose two washing jigs (one Luhring and one New Century) have been installed, together with a Williams crusher. To remove the moisture from lignite and washed coal there is a Bartlett rotary dryer. The three coke ovens are of the Semet-Solvay type, but the smoke and gases are carried by flues to the furnace of a 100-HP. Frost boiler. Gas from the producer can also be used to heat the ovens, if desired. The coke will be tested in the foundry of the Exhibition.

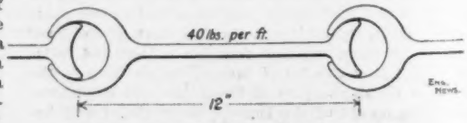
All the machinery and equipment for this plant have been furnished by manufacturers and [illegible]

Fig. 3. Section of Drill Holes, Straight and Chambered.

ported by railways free of charge, as the act under which the appropriation was granted prohibited payment for plant and transportation, the intention being that the money should be spent in the actual work of testing.

THE BEHREND STEEL SHEET PILING.

A new style of steel sheet piling has recently been introduced in which each pile is a single piece, complete in itself without rivets, bolts or other attachments. The piles are of a special rolled section, consisting of a flat web with a cylindrical rib on each edge, the outer end of each rib being slotted, as shown in the accompanying cut. The ribs are not the same diameter, but the smaller rib of one pile fits easily within the larger rib of the adjacent pile, while the slot admits the web. This allows some flexibility in changing the direction of the line of piling, but



Section of Behrend's Steel Sheet Piling.
United States Steel Piling Co., Chicago, Makers.

for turning corners there is a special section of pile having the web bent in a curve or at an angle. The joints can be made watertight by packing them with suitable material. The cut shows piles for a spacing of 12 ins., weighing 40 lbs. per ft., but they will be rolled in several sizes, according to the length and character of the work.

This form of sheet piling is the invention of Mr. Samuel K. Behrend, and is manufactured and sold by the United States Steel Piling Co., 135 Adams St., Chicago.

ENGINEERING NEWS

A Journal of Civil, Mechanical, Mining and Electrical Engineering.

Entered at the New York Post-Office as Second-Class Matter. Published every Thursday at St. Paul Building, 220 Broadway, New York, by

THE ENGINEERING NEWS PUBLISHING CO.

PUBLICATION OFFICE, 220 BROADWAY, NEW YORK.
CHICAGO OFFICE, 1636 MONADNOCK BLOCK.
BOSTON OFFICE, 170 SUMMER ST.

FOREIGN AGENTS.

C. MITCHELL & Co, Snow Hill, Holborn Viaduct, LONDON.
RUDOLF MOSSE, BERLIN and HAMBURG, GERMANY.
JOHN F. JONES, & CIE, 31 Rue de Faubourg Montmartre, PARIS.

SUBSCRIPTION RATES: United States, Canada and Mexico, One Year, $5.00; 6 months, $2.50: 10 weeks, $1.00. To all other countries in the Postal Union: Regular Edition, One Year, $8.00; Thin Paper Edition, One Year, $6.75. SINGLE COPIES of any number in current Volume, 15 cents.

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The serious accident to an electric car at Melrose, Mass., due to an explosion of dynamite, which is noted elsewhere in this issue, calls attention again to the ever-present danger involved in transporting dynamite by wagon through city streets. Ordinances in several of the larger cities prescribe the use of wagons especially designed for the transportation of explosives and the marking of the wagons in such a way that their character may be known at a glance. The importance of care in this particular is made evident by the lamentable accident in Melrose which cost the lives of ten persons. It appears that a 50-lb. box of dynamite fell from the rear of a delivery wagon, and, before the driver could return to remove it from the street car track where it had fallen, an electric car struck the box and exploded its contents. Doubtless some of the sticks of dynamite were ground under the wheels of the car until one of them exploded, thus firing the rest of the dynamite.

Notwithstanding the fact, now well known to all who have investigated the subject, that dynamite can be, and frequently is, exploded by severe mechanical shocks, there is a woeful lack of caution on the part of those who are accustomed to handle dynamite. Within a few weeks there have been two accidents to children in New York City due to carelessness in leaving sticks of dynamite where boys could find them. In one case a boy picked up a stick of dynamite and began whittling it, which resulted in his hands being blown off. In another case a boy was seriously injured while batting a piece of dynamite with a stick.

Every city should at least make an effort to lessen the chances of accidents by the enforcement of ordinances requiring the greatest of care in the transportation, storage and thawing of dynamite. It is stated that Melrose, which is a city of 13,000, has no ordinances or rules governing the handling of explosives within the city limits, and doubtless Melrose is no striking exception in this matter. In our issue of Dec. 18, 1902, an abstract was given of the rules formulated by the Municipal Explosives Commission of New York, which, so far as we know, are the most rigorous and definite rules yet adopted by any American city. They are by no means all that they might be, but certainly they are infinitely better than nothing.

The economy of steam engines which run continuously (such as those of central power stations) can be carried to a very high degree by the adoption of multiple expansion and the installation of superheating and condensing apparatus. But with engines which run intermittently (such as rolling mill engines and mine hoisting engines) the conditions are not favorable to economy in steam consumption; condensers cannot be run to advantage with the irregular exhaust, and in nearly all cases the engines are run non-condensing. This leads to a very great reduction in economy and consequent high cost of operation for the power developed. A system is now in use in Europe by which this waste energy is utilized and the economy of the plant thereby greatly increased. In brief, this system (which is described in another column) consists in delivering the exhaust to a regenerating apparatus which will absorb a certain proportion of the steam during the period of exhaust and give out steam when the pressure falls during the period of rest. With this apparatus, the irregular flow of exhaust steam is transformed into a continuous flow which is delivered to a low-pressure turbine working under a good vacuum, and operating dynamos, pumps, fans, or other auxiliary plant. When the exhaust is insufficient to supply the demand, or when the engine is shut down for longer periods than the regenerator is designed for, live steam is admitted to the turbine, thus taking steam from the boilers at a time when (as the engine is not working) they would otherwise be very likely to waste steam by blowing-off at the safety valve. The use of the apparatus does not affect the working of the main engine, but simply utilizes the waste energy of the exhaust steam.

The regenerator may also be adapted to other purposes besides the working of turbines. Thus with a number of engines, all working intermittently the several exhausts may be delivered to a regenerator which will give a uniform flow of steam, to a condensing plant, thus enabling the latter to work with greater efficiency.

Some turbo-regenerator plants on this system have been in operation in Europe for over two years, developing from 350 to 2,500 HP. from steam formerly exhausted into the atmosphere and wasted. It is stated that the plants now in use or under contract represent an aggregate of some 30,000 HP. The system is the invention of Mr. Rateau, of Paris, the inventor of the Rateau turbine, and arrangements are being made for its introduction into this country, where the first application will probably be to the engine of a large slabbing mill. The idea is certainly an interesting and promising one in the line of steam economy, and is made practicable by the introduction of the steam turbine, which is itself of very recent date as far as commercial application is concerned. It would, of course, be theoretically practicable to use the steam from the regenerator in a reciprocating engine, but the size of cylinder required to develop power with a mean effective pressure throughout the stroke of only 5 to 8 lbs. per square inch is a handicap in the way of such an application.

Further examples of the use of copper sulphate on a large scale for the elimination of algae from water-works reservoirs are given in our columns this week. Two storage reservoirs at Baltimore were treated in midsummer with apparently satisfactory results. It is true that analyses made a month or so after the treatment showed a greater total number of algae in the reservoirs than before the treatment, but we understand that these were particularly resistant species, were not the ones for which the treatment was designed and, most important of all, that their appearance has not given rise to serious complaints from bad tastes or odors in the water.

The recent convention of the New England Water-Works Association at Holyoke, Mass., was generally considered by those in attendance to be one of the most successful in the life of the association. In the past few years the association has made several meritorious changes in its business methods. It still has an opportunity to take one long step forward and should it improve that opportunity it would thereby raise itself still higher than it now stands among the technical societies of America. The step which we would propose, and which has already been given at least private consideration by some of the officers of the association, is the publication of papers in advance of the meetings at which they are to be read. Good as was the Holyoke convention there was comparatively little discussion on that occasion. As is well known, the publication of papers in advance enables those in attendance at a convention to be ready to discuss the papers when read, and, perhaps more important, it enables such members as cannot get to the convention to send in written discussions.

It is often true that the best service rendered by a society paper is the discussion which it brings out. The Journal of the New England Water-Works Association affords a reasonably prompt means of bringing papers and discussions before the members of the association. Unquestionably, too, the Journal has been one of the most important factors in building up the association and particularly in transforming it from a local or sectional to a national organization. More discussions would add to the value of the Journal and thus contribute materially to the prosperity and usefulness of the association.

SOME SPECIFICATIONS FOR CAST-IRON PIPE.

Specifications relating to the payment to be made for cast-iron pipe by weight should be explicit in order to avoid disputes. The following abstract from a recent specification serves as a good example:

> The proposal shall state the price per ton of 2,000 lbs. for all sizes of pipes mentioned in the schedule, f. o. b. cars at the city of ———.
>
> All pipes that fall short of the minimum weight given in the schedule shall be rejected, and no weight will be allowed or paid for that shall exceed the maximum weight given in the schedule.

Schedule.

		Weight of a length in lbs.		
		Standard.	Maximum.	Minimum.
Internal diam.,	3-in.....	145	150	140
" "	4-in.....	216	223	208
" "	6-in.....	360	372	347
" "	8-in.....	480	497	463
" "	10-in.....	640	662	618
" "	12-in.....	860	890	830
" "	16-in.....	1,260	1,298	1,222
" "	20-in.....	1,800	1,854	1,746
" "	24-in.....	2,500	2,575	2,425
" "	30-in.....	3,500	3,605	3,395
" "	36-in.....	4,700	4,841	4,559
" "	48-in.....	8,400	8,652	8,148

It will be observed that the allowable variation in weight from the standard is 3%.

Passing now to some other clauses of this specification, we note one that is particularly reprehensible, because it plays "fast and loose." It reads somewhat as follows:

> The Board of Public Works reserves the right of continuing this contract so as to include all the pipe required by the department during the year, or cancelling it when the amount is delivered as above specified. In the event of the contractor failing to deliver pipe as above specified, he will forfeit the sum of $5 per ton for each and every ton not delivered as above specified.

What moral right, may we ask, has any party to a definite contract to insert a clause permitting him to waive one of its provisions without permitting the other party to do the same? Manifestly the object in inserting such a clause is to get pipe at a lower price than the market rate, should it happen that the price of pipe should rise subsequent to the delivery of the tonnage called for in the schedule. We see in this clause the ever-present tendency to draw contracts so as to put the contractor on a losing basis, should unforeseen conditions arise. Does any one imagine that if the cast iron pipe were to drop in price, say, $2 a ton, that the Board would continue to buy under its contract any considerable amount of extra pipe that might be needed? Let us put these questions in plain words to ourselves, and we shall find our sense of justice demanding a rewriting, if not an entire elimination of clauses that mar otherwise good specifications.

Looking at this particular clause from another point of view, we may well question its legality as

applied to public work contracts in States where statutes require letting to the lowest responsible bidder. The courts have held that any great change in the original contract, subsequent to its award, serves to nullify the contract, for were this not the rule it would be an easy matter for corrupt officials to evade the law entirely. A large increase in the quantity of any item over that shown in the schedule of quantities is obviously a change that might greatly assist a contractor who has submitted an unbalanced bid.

In a word, there are several good reasons why no such clause as this should be suffered to exist; and such reasons as may be advanced in its favor are entirely outweighed.

One more question: Why should a $5 forfeit per ton be inserted for non-delivery, when the contractor is required to execute his contract under bond? There may be some case of record where the courts have upheld a claim for such a forfeit, although we doubt it.

A clause in another recent specification relating to cast iron pipe contains the following paragraph:

No pipe shall vary from the specified weight more than 5%, and the total weight of the pipe furnished shall not differ materially from the weight as figured on the basis of weights specified. The exact weight of each pipe and special shall be marked plainly on the inside of the bell. The unit price shall be per ton of 2,000 lbs. delivered f. o. b. cars at .....

There is but one feature of this clause that lacks definiteness. Instead of prescribing that the total weight of pipe shall "not differ materially" from the specified weight, some more definite expression than the adverb "materially" should be used.

COMMENTS ON SPECIFICATIONS FOR PROTECTING EMBANKMENT SLOPES.

Specification clauses governing the seeding of embankments are seldom to be found when wanted in drawing specifications, for which reason the following clause from an Ohio specification may well be placed on record:

The Contractor shall seed all surfaces of the embankments which have been finished with top soil and other surfaces as may be directed.

The surfaces to be seeded shall be carefully prepared and raked over and then seeded with grass seed, using at least 50 lbs. per acre, and consisting of a mixture of 4 parts beech grass, 4 parts Hungarian brome, 4 parts orchard grass and 1 part of white clover, together with not less than 400 lbs. of raw bone fertilizer per acre, and all well rolled. All seeded surfaces shall be carefully tended by the Contractor, shall be watered and the grass cut when necessary, and shall be turned over to the city in good condition on the final acceptance of the work.

The protection of slopes with a slope-wall or stone paving is often specified, but seldom are the specifications drawn with good judgment, unless the engineer has had considerable experience in this class of work. The following clause will serve to illustrate some of the common errors of omission and commission:

The paving blocks shall be hard, durable limestone, free from cracks and flaws. They shall be even faced, straight edged stone, approximately rectangular in shape at the faces, and so split or dressed as to give a joint not exceeding 1 in. anywhere at the face, and not exceeding 3 ins. at any point. The stone shall be from 20 to 30 ins. in length, not less than 8 ins. in width, and approximately 18 ins. in depth, measured at right angles to the slope. The paving shall be laid in regular courses, with the heavier courses at the bottom. The cross-joints shall break joints at least 10 ins., and, after the stones have been set, all joints shall be filled with clean gravel, and the faces of the joints shall be thoroughly chinked with spawls well driven in. In case of any sliding or settling, the work shall be reconstructed.

In the drawing of specifications for slope wall masonry of this kind it is essential, if economy is aimed at, to examine the quarry from which the stone is likely to come. There are many limestone quarries having thin bedded upper layers which may be split with a hammer to stones ranging from 4 ins. to 12 ins. thick on the face. In other limestone quarries it requires plug and feather work to split the stone into desirable sizes. In the latter case there is no objection to naming 8 ins. as the minimum thickness of a course, for it can be relied upon that the contractor will split his stone as thick as can be handled without a derrick in the laying. On the other hand, stone found in thin beds that can be split with hammers, without plug and feathering, should not be limited in thickness to 8 ins., for an excellent slope wall can be built of 4-in. stones.

Another feature of this specification that will add to the cost of the work, without adding to the durability or serviceability of the wall, is the requirement that the wall shall be laid in "regular courses." These two words look innocent enough on paper, but we have known instances where they have actually doubled the cost of a slope wall. There is no necessity of laying a slope wall as if it were a street pavement, in regular courses. So long as the stones are well bonded by overlapping, and not more than, say, three thin stones are placed one above the other to equal the thickness of a large stone, the wall can be counted upon to serve its purpose. A 10-in. overlap, as above specified, means the use of no stone less than 20 ins. long, and the breaking of joints precisely in the middle of such stones. This again is wholly uncalled for in slope-wall masonry. An overlap of, say, 4-ins. (except where two or three stones are used to even up with an adjoining thick stone) is sufficient for all practical purposes. The minimum length of stones may then be reduced to, say, 10 or 12 ins.

There appears to be an unfounded fear that comparatively small stones in a slope wall on a river bank will be displaced either by ice, driftwood or boats. But the fact is that a slope wall of comparatively small stones, bonded as above outlined, has a remarkable resistance to displacement, as may be readily tested by an attempt to remove any one of its stones with a pinch bar, and as may be ascertained by examining old walls that have been subjected to no slight amount of ice pulling and battering.

As to the depth of a slope wall on a river bank, from 12 to 16 ins. will suffice if the wall is properly "lined" (i. e. backed) with gravel or broken stone. The clause under discussion makes no such provision, and is consequently a poor clause for general use. Eddies of water will tend to wash out the earth back of the slope wall in spots, causing settlements; and the flow of rain water down the slope back of the wall will be even more destructive in many cases. It is true that the clause calls for chinking of the joints with gravel and spawls, but gravel of a size that can be swept in with a broom can be swept out by a current of water; and, as for spawling face joints only one inch wide, we may add that it is one of those provisions that look well on paper but do not work out so well in practice. Moreover, neither of these methods protects the wall from settlements due to the washing away of the earth back of it by descending rain water.

Finally, we may say that 1-in. face joints are usually not to be had, except at an expense wholly incommensurate with any advantage thus obtained. There are, it is true, some very flat bedded stones in certain quarries, but we are now speaking of the general run of stone used for slope wall purposes. Where granites are to be used, the specifications must be far more lenient in the matter of sizes and dressing than we have indicated, if a reasonably cheap slope protection is to be secured.

Embankments are not so often protected by sodding as they would be were it not for the cost, which usually ranges from 6 to 25 cents per square yard. That it is not necessary always to cover the full area of a slope with sod is apparent, yet how small a percentage of the full area may be sodded with satisfactory results is not often considered. The following clause from a levee specification bears upon this point:

After the embankment is built to the proper lines and dimensions it shall be smoothly dressed to proper slopes and the entire surface planted with living sods of Bermuda grass not less than 4 ins. square, placed not more than 2 ft. apart. The sods shall be covered with 1 or 2 ins. of earth as directed.

If these squares of sod are placed 2 ft. c. to c., they form less than 3% of the total area; but if they are placed 2 ft. apart in the clear, as the specification seems to permit, they cover only 2% of the total area. In our issue of June 2 some excellent data on the actual cost of sodding were given. We shall welcome more data on the same subject, particularly the cost of sodding in patches as above described.

LETTERS TO THE EDITOR.

A Table for the Computation of Sinking Funds.

Sir: During the year 1897 there was published in Engineering News a table relating to sinking funds, by which quick computations could be accurately made, and a great amount of detail, and tedious labor was avoided by its use.

On behalf of others and myself I request you to republish it for general service to the engineer, and others identified with construction and finance.

Very respectfully yours, John Jerome Deery.
Betz Building, Philadelphia, Pa., Sept. 13, 1904.

(The table to which our correspondent refers was published in connection with a paper on the calculation of sinking funds, by Mr. Peter Mogensen. Inasmuch as it may be of use to many present readers who were not on our subscription list seven years ago, we reproduce it herewith. The only explanation needed is that the vertical column headed n is the number of years from the date of investment to the maturity of the sinking fund and the horizontal line r represents one dollar with one-half year's interest added:

The table was computed by the formula:

$$\frac{A}{C} = \frac{r^2 - 1}{r^2\, n - 1},$$

In which interest is assumed to be compounded half yearly, and

A = annual instalment, the first payable one year after investment and the last one at the end of n years.

C = total capital invested.

r = one dollar with one-half year's interest added.

n = number of years from investment to the maturity of the sinking fund, when the latter will become equal to the capital originally invested.—Ed.)

ANNUAL PAYMENTS TO A SINKING FUND NECESSARY TO ACCUMULATE ONE DOLLAR AT THE END OF A GIVEN NUMBER OF YEARS.

Int. per ann. / n	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
r	1.005	1.010	1.015	1.020	1.025	1.030	1.035	1.040	1.045	1.050
2	0.4975	0.4951	0.4923	0.4903	0.4877	0.4853	0.4829	0.4803	0.4781	0.4754
3	0.3298	0.3202	0.3235	0.3199	0.3170	0.3135	0.3106	0.3076	0.3044	0.3014
4	0.2463	0.2425	0.2389	0.2353	0.2318	0.2285	0.2248	0.2214	0.2180	0.2147
5	0.1953	0.1916	0.1881	0.1845	0.1807	0.1771	0.1734	0.1699	0.1664	0.1630
6	0.1625	0.1585	0.1548	0.1506	0.1468	0.1431	0.1394	0.1358	0.1322	0.1288
7	0.1387	0.1345	0.1304	0.1265	0.1226	0.1188	0.1151	0.1115	0.1080	0.1046
8	0.1206	0.1165	0.1124	0.1084	0.1045	0.1007	0.0970	0.0935	0.0900	0.0867
9	0.1061	0.1025	0.0983	0.0943	0.0904	0.0867	0.0831	0.0795	0.0761	0.0729
10	0.0953	0.0913	0.0871	0.0832	0.0793	0.0755	0.0719	0.0685	0.0652	0.0620
12	0.0788	0.0745	0.0704	0.0664	0.0626	0.0590	0.0555	0.0522	0.0491	0.0461
15	0.0620	0.0577	0.0537	0.0498	0.0462	0.0427	0.0394	0.0363	0.0335	0.0308
20	0.0453	0.0411	0.0371	0.0334	0.0300	0.0269	0.0241	0.0215	0.0191	0.0170
25	0.0353	0.0311	0.0273	0.0239	0.0208	0.0179	0.0155	0.0133	0.0114	0.0096
30	0.0287	0.0246	0.0209	0.0177	0.0149	0.0124	0.0104	0.0086	0.0071	0.0058
35	0.0239	0.0199	0.0165	0.0135	0.0109	0.0087	0.0070	0.0056	0.0044	0.0035
40	0.0204	0.0165	0.0132	0.0104	0.0082	0.0062	0.0048	0.0037	0.0028	0.0021
45	0.0177	0.0139	0.0107	0.0082	0.0062	0.0046	0.0034	0.0025	0.0018	0.0013
50	0.0154	0.0118	0.0088	0.0064	0.0047	0.0032	0.0024	0.0016	0.0011	0.0008
60	0.0122	0.0087	0.0060	0.0041	0.0028	0.0018	0.0012	0.0007	0.0005	0.0003
70	0.0099	0.0065	0.0043	0.0028	0.0017	0.0009	0.0006	0.0003	0.0002	0.0001
80	0.0082	0.0051	0.0031	0.0018	0.0010	0.0005	0.0003	0.0001	0.0001	0.0000
100	0.0059	0.0032	0.0016	0.0008	0.0004	0.0002	0.0001	0.0000	0.0000	0.0000

Economy in Coal Handling.

Sir: Large users of power are gradually coming to appreciate the economy of automatic machinery in superseding manual labor, so that the mechanical stoker and the coal conveyor are now found in the majority of new steam plants which are rated above 10,000 KW. In fact, it is difficult to draw any hard and fast line below which the fireman's muscle and shovel can compete successfully with automatic machinery, because the conditions of operation in different plants vary so widely. There is little doubt, however, that many plants of from 500 to 5,000 KW. rated capacity are suffering from a lack of the most improved fuel-handling equipment, and that a noteworthy saving in the cost of bringing the fuel to the boilers could often be realized by strengthening the weak spots of the coal-handling system.

The subject may be profitably studied from the industrial point of view, which looks upon the fuel as the raw material and the current output as the completed product of a somewhat complex manufacturing establishment. Our English cousins are not so far wrong after all in denominating their electric plants as "Electricity Works," although it sounds a bit odd to American ears.

In examining a power station with a view toward reducing the operating cost of the fuel handling system it must be borne in mind that elaborate apparatus is justified only in cases where the output of the plant is large.

and where the proportional cost of attendance is moderate, as far as that particular equipment is concerned. Simplicity is always desirable in small and medium sized installations. Frequently the desired gain in efficiency may better be secured by improving the existing equipment than by tearing it all out and putting in entirely new apparatus.

A case in point is that of a 2,250 KW. Colorado plant situated in an extraordinarily favorable position as regards its coal supply. The power house is located at the bottom of an easy grade some 350 yards from a coal mine. Coal is brought to a weighing and dumping shed outside the plant by two hopper cars which run upon a 3-ft. gage railway, and carried into the main building by a conveyor operated by a 3½-HP. motor. Each car weighs 2,040 lbs. and holds 3¾ tons of coal, and the two cars run by gravity, one coming down loaded while the other returns empty to the mouth of the mine shaft. About 150 tons of coal are burned each day; the cost of the fuel is about $1 per ton and the expense of handling and weighing it not far from 5 cts. per ton. Three shifts of one man each are required to take care of the coal machinery and weigh each car as it arrives.

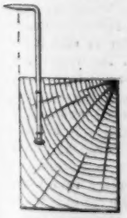
At first blush this appears to be a thoroughly modern system of coal handling, and certainly compares favorably with more than one other installation in present day operation. A detailed examination of the system, however, brings to light several points which suggest a possible saving in operating expenses of at least $1,400 per year—not a large sum, but one which it is decidedly worth while to have upon the credit side of the balance sheet. The weak spot of this particular system is the cost of labor. This arises from the delay of each car at the weighing and discharging house, which cuts down the movement of coal per man to a serious degree. The loaded car stops on its down trip just short of the scales; the attendant is then obliged to push it upon the scales and to weigh it, after which another long back-breaking push carries the car to the mouth of the hopper pit. The attendant unlatches the bottom of the car and about two-thirds—sometimes but half—its contents are dumped into the pit to be carried away to the coal bins by the conveyor. The remainder has to be shoveled from the cars because of its faulty design, and finally the emptied car has to be slowly pushed backward some 20 or 30 ft. to the cable clutch before it can be hauled up-hill again. All this manoeuvering takes time, and as the attendant is required to keep a close watch upon the conveyor system's workings, the average number of car loads per man falls to a bare baker's dozen per day.

The redesigning of the cars and installation of an automatic recording scale would undoubtedly enable the entire supply of coal per day to be weighed and carried to the bins during the working hours of one man. This would result in a gross saving of the wages of two men at $2.37 per day, or about $1,700 per year. Capitalized at 6% this comes to $28,000, in round numbers. It is difficult to see how the cost of installing a self-recording scale, with the mechanism for receiving the loaded car, stopping it upon the scale, weighing it, releasing it and automatically discharging the contained fuel completely into the pit should exceed $5,000. This means that it would pay the operating company to spend over $20,000 in improving its conveyor system, and that the cost of handling each ton of coal, exclusive of depreciation, which may be assumed to be about constant in view of the shortening of the conveyor travel which a slight relocation of the weighing shed would permit, would be reduced to about 1¼ or 2 cts. per ton. The sum of these small economies makes for increased net earnings, and it is certainly well worth while for every progressive manager to satisfy himself that similar opportunities do not pass unheeded upon his own system. H. S. K.

Minneapolis, Minn., Sept. 14, 1904.

Measuring Deflections in Floor Tests.

Sir: In reference to the very practical "method of measuring deflections in floor tests," as explained by Mr. Edward Godfrey in your issue of Aug. 25, I wish to offer the following modification in the manner of obtaining the measurements. Instead of the piece of paper on the back of the upright, get a common sharp pointed pin of large size and bend it about a quarter of an inch back of the point, so that the point will be about at right angles with the shaft. Fasten this pin to a small block of wood by means of two very small staples, having it project far enough beyond the block (say an inch) so that a light tap at back of the elbow will cause it to spring forward. Now nail this block against the upright in such a position that the pin point will be as near as possible to the piece of paper on the joist without touching the same; and this piece of paper need have no graduations. To make the observations, prick this paper with the pin point at such times as desired. This method facilitates the field work at the expense of the office work; does away with the necessity of setting the papers at the zero line; permits a careful reading of the deflections in the office with a good scale; and allows a check to be made on the readings.



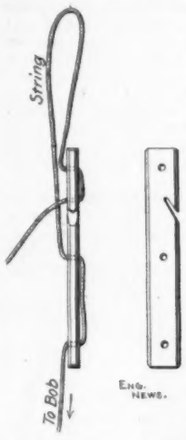
Very truly,

Chas. H. Miller, M. Am. Soc. C. E.

727 East End Ave., Pittsburg, Pa., Aug. 29, 1904.

A Device For Adjusting A Plumb-Bob String.

Sir: The accompanying sketch illustrates a simple device for use on the plumb-bob string of a transit. It consists of a piece of rubber comb about 2½ ins. long and ½-in wide, provided with three holes and a slot between the middle and top holes. The string is threaded through the holes as shown, and the loop hooked over the hook on the transit chain. After adjusting the bob to the proper height, the free end of the string is caught in the slot so as to hold it from slipping.



Yours truly,

E. L. Colburn.

Snohomish, Wash., Sept 15, 1904.

(Another simple device to accomplish the same end, is a piece of wood pierced with two holes, the string from the bob passes through the lower one and the free end of the string is tied in the upper one. With wood of the right thickness there is friction enough in the passage of the cord through the lower hole to hold the plumb-bob in any position, and it can be moved up and down as desired without any adjustment of knots.—Ed.)

High or Low Elastic Limit Steel for Reinforcing Concrete.

Sir: I cannot agree with Mr. Watson's comment on Prof. Arthur N. Talbot's paper in your issue of September 1. Mr. Watson fears that the minute cracks which, according to Prof. Talbot, probably exist in concrete steel beams in the second stage of loading, are a great source of deterioration to the imbedded steel, and at the same time greatly reduce the fireproof qualities of this composite material.

Mr. Considère pointed out some five years ago, and Prof. Hatt of Purdue University two years ago, that reinforced concrete allows of elongations of 1-1,000 to 2-1,000 of its length without the least sign of cracks, a fact which was conclusively proven by tension tests on bars of plain concrete, which were cut out of test pieces of reinforced concrete which had been subjected to this great elongation, and which plain concrete bars showed the same ultimate strength as common concrete bars.

According to Prof. Talbot the first stage of loading is reached when the lower fibers are elongated to 1-10,000 to 1-7,500 of their length; that is 1-10 to 1-20 of the elongation which reinforced concrete may sustain without cracking; therefore it is clear that the minute cracks in the concrete cannot happen before the end of the second stage, which Prof. Talbot defines as the stage where cracks are not yet visible.

Although Prof. F. E. Turneaure, in his paper published in your issue of Sept. 8, believes he has demonstrated the appearance of cracks in the early part of the second stage, his experiments are too much in contrast with Mr. Considère's careful investigations to be accepted without further proofs.

Assuming even that microscopical cracks exist, does Mr. Watson really believe that these cracks would cause deterioriation of the steel rods? Certainly not. The steel rods in the medium wet concrete which is now generally used in this construction, are coated by a thin film of cement which absolutely prevents deterioration in ordinary construction. If somebody doubts the formation of this film let him specify the rods to be coated by cement before the concrete is placed.

French railroads paint their bridges with cement instead of the paint heretofore used, and experience proves it a great success. General Sooysmith mentioned in a discussion on reinforced concrete construction, at a meeting of the Western Society of Engineers, that he found common whitewash was a far better preserver of steel than any paint he ever used.

Mr. Watson contends that reinforced concrete beams at the specified load should never exceed the first stage of loading, and, as steel of a low and a high elastic limit has the same effect in this first stage on the behavior of the beams, he does not see any use for steel of high elastic limit, especially as mild steel is a more reliable material. On the other hand we know by theoretical consideration, as shown by Mr. Considère and many others, and by tests made here and abroad, that steel of a high elastic limit, as drawn wire, twisted steel, and high carbon steel, increases the second stage of loading and the ultimate strength often 50%, and therefore steel of a high elastic limit has a positive advantage if used as a reinforcing member.

Quite another question is: Whether the use of steel of high elastic limit is also of economical advantage. Medium steel bars cost 1.35 cts. per lb., f. o. b. Pittsburg. Steel of a high elastic limit should cost less than 1½ times 1.35 cts., that is 2.025 cts. per lb., to be of economical advantage. Drawn wire costs not less than 3½ cts. per lb., and is therefore uneconomical. Twisted steel bars cost about 2 cts. per lb., and are therefore not superior to mild steel rods as a reinforcing member. Corrugated bars cost 2¼ to 2½ cts. per lb., hence entail an extra expense of 10% to 25% over the use of mild steel rods.

High carbon steel bars are sold by many rod mills at 1.45 cts. to 1.50 cts. per lb. and this kind of steel rods offers a saving of more than 25% over mild steel; or, if we use them in the same quantity as we use mild steel, we obtain by an extra expenditure of only 10% of the cost of the bars, an increase of strength of nearly 50%.

Of course this holds true only of low percentages of reinforcement, as in beams more highly reinforced by steel the ultimate strength depends on the crushing strength of the concrete.

Mr. Talbot omitted to make tests on plain steel bars of a high elastic limit, which bars are more extensively used than some of the bars he experimented with, for example, in the form of wires in the so-called Clinton, Metropolitan, International, Matral, Cottancin, etc., systems of reinforced concrete construction. High carbon plain steel bars are used by many prominent concerns in this country.

Many engineers believe that the greater adhesion of some bars is the cause of the greater efficiency. Thacher bars which were of mild steel, and which have certainly a greater adhesion than plain or twisted steel bars, did not show any better results than bars of mild steel.

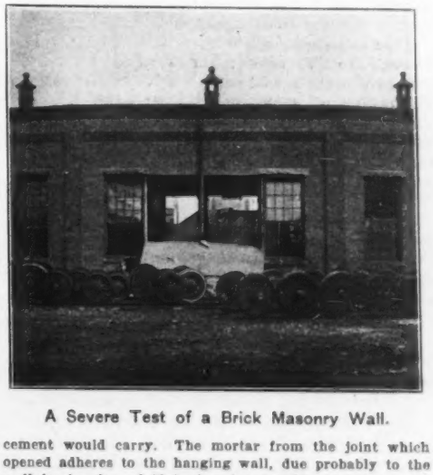
To sum up I wish to say that plain steel bars of high carbon steel are the most economical material for reinforced concrete construction, a fact also shown by the tests published in the above-mentioned paper of Prof. F. E. Turneaure. Truly yours, L. J. Mensch.

Monon Bldg., Chicago, Ill., Sept. 12, 1904.

Good Brick Masonry Laid With Lime-Cement Mortar.

Sir: I enclose a photograph of a roundhouse wall showing an exceptionally good specimen of brick masonry. The wall was punched out by a locomotive having a defective valve. The windows are 11½ ft. apart in the clear and 4 ft. wide, making the total span at the break nearly 20 ft. The hanging wall not only carries itself but for some hours carried also two roof trusses of 37 ft. span spaced 13 ft. apart which brings their feet nearly over the inner sides of the windows. Of course temporary posts were put under the trusses as soon as possible after the break.

The walls were laid in January or February, 1903, with mortar of about 2 parts lime, 1 part Portland cement, 9 parts sand, or about all the sand that the lime and



A Severe Test of a Brick Masonry Wall.

cement would carry. The mortar from the joint which opened adheres to the hanging wall, due probably to the wall having been laid in freezing weather and the break between two days' work coming at this joint.

As masonry rarely holds so well in tension, possibly the print is worth publication. H. K. Higgins,

Asst. Engr., N. Y., N. H. & H. R. R.

472 So. Sta., Boston, Mass., Sept. 13, 1904.

(Another evidence of the excellent quality of the masonry is the large piece of the wall which was broken out by the locomotive and which lies almost intact.—Ed.)

Notes and Queries.

In the titles to the illustrations of the Louisiana Exposition Buildings published in our last issue, the names of the architects of the Education Building (Fig. 1, p. 258) and of the Liberal Arts Building were transposed. The

architects of the Education Building were Eames & Young, of St. Louis, and the Liberal Arts Building was designed by Barnett, Haynes & Barnett, also of St. Louis. Credit for the design of the Transportation Building should also be given to Mr. E. L. Masqueray, Chief of Design, although Mr. I. S. Taylor, Director of Works, had general supervision. The U. S. Government Building was constructed by W. O. & C. G. Burton, of Richmond, Va., and not by Strehlow & Phelps, as stated.

REARRANGEMENT OF TRACKS AND STATION FACILITIES AT THE UNION STATION, ST. LOUIS, MO.

The Union Terminal Station at St. Louis, Mo., is one of the largest railway stations in the world (if not in fact the largest),* but since its construction in 1892, the rapid growth of traffic has overtaxed the track capacity and the station accommodations. Alterations have been in contemplation for some time, and were finally undertaken last year in view of the necessity of providing for an exceptional increase in traffic on account of the St. Louis Exhibition. The conditions were carefully studied by the executive officers of the Terminal Railroad Association of St. Louis, and a comprehensive scheme of improvement and reconstruction was adopted, which has been carried out under the general direction of the President, Mr. W. S. McChesney, Jr. The work is now almost completed, and for information and drawings respecting it we are indebted to Mr. Daniel Breck, Chief Engineer; Mr. J. L. Armstrong, Engineer of Maintenance of Way; and Mr. A. P. Greensfelder, Assistant Engineer, of the Terminal Railroad Association. The work may be considered under five heads: 1, The track system; 2, The engine terminal facilities; 3, The mail, express and baggage facilities; 4, The power plant; 5, The passenger station or head-house.

THE TRACK SYSTEM.

The station has a trainshed 601 ft. wide and 810 ft. long (originally 630 ft.), covering 32 tracks, arranged in pairs. In the track system as originally laid out (see Fig. 1), the approach consisted of a single four-track throat through which every train, engine and switching movement of the passenger service had to pass. In addition to this, the switching of cars to and from the express tracks had to be done over one of these four tracks. This throat was closely shut in on the west by yard tracks and on the east by a row of buildings for the express companies. Beyond the throat, the tracks diverged in both directions to connect with the main tracks, which are at right angles to the station tracks. In the triangular space between the Y and main tracks was the signal cabin, controlling all train movements by means of an elaborate switch and signal interlocking plant. Owing to the wide spread of the leads from the central throat to the station tracks, the tracks at each side of the trainshed were only long enough to accommodate an engine and six or seven cars, while those in the middle of the trainshed could accommodate an engine and twelve cars.

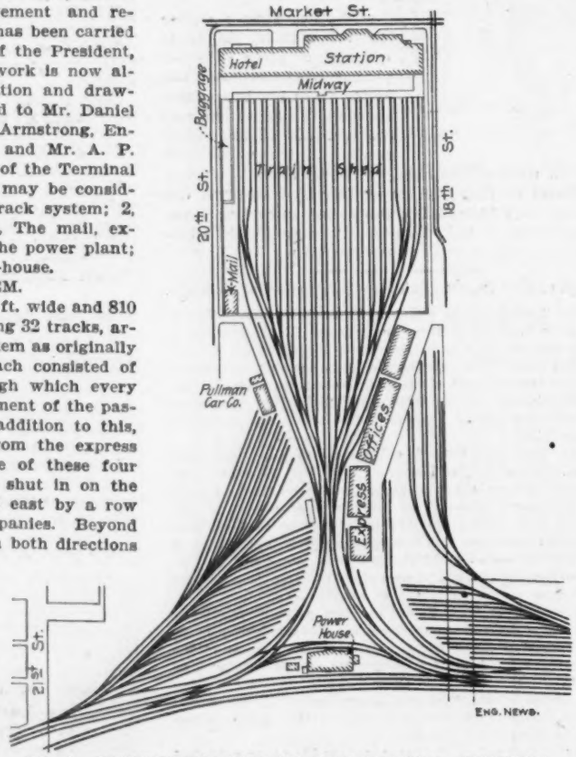


FIG. 1. ORIGINAL TRACK PLAN AT THE UNION TERMINAL STATION, ST. LOUIS, MO.

It will be seen from this general description that not only were the arrangements calculated to cause congestion and delay, but that any extensive improvement would involve practically an entire reconstruction of the track system, including both running tracks and yards. Furthermore, this work would have to be done in the face of a heavy and growing traffic. Fig. 1 is a plan of the track system as originally built, and an examination of this will enable the scheme of alterations to be more fully comprehended. It should be noted that east and west of the station are a series of yards for passenger cars, opening from the through main tracks, which are at right angles to the station tracks. As one of these (adjacent to the station approach on the west) had to be abandoned, one of the first steps necessary was the provision of new yards to accommodate the cars before the old yards could be given up. A paper read before the American Association for the Advancement of Science by Mr. A. P. Greensfelder, presents a general description of the conditions met with and the alterations recently made by the Terminal Railroad Association. That part of the paper relating to the Union Station is as follows:

In the last few years gigantic strides have been made in the enlargement of railway facilities all over the country, and particular attention is being given to methods which tend to diminish the necessary labor for handling business. In the large cities the question of ample terminal facilities is a vital one. As the practical working capacity of a railway is often determined by its terminals, and as such necessities require expensive construction on valuable real estate, it is evident that the proper solution of such problems of construction with their co-ordinate economic factor is a matter of very great importance. The proper function of railway terminals is to recognize two separate factors: 1, the transportation of cars, including the necessary switching; and, 2, the storage of cars while awaiting loading or unloading, or until their proper distribution can be made.

St. Louis, with the fourth largest population of the cities in the United States and the center of 22 different railways, presents an example of what railway concentration can imply. Together with other large cities, it has its problem of the handling of the varied freight and passenger business for solution, and due to the enormous increase of both kinds of traffic, large increases in terminal yards and structures were deemed necessary. All passenger business is handled from one union station, and a large percentage of the total tonnage of local freight and freight interchange is transferred from one railway to another through the medium and under the direction of what is known as the Terminal Railroad Association of St. Louis. This Association is composed of 14 of the railways entering St. Louis or East St. Louis and was formed by them for the rapid and economical handling of freight and passenger traffic through the city.

A proper discussion of a large railway terminal station must include, not only the station house itself, with its trainshed and approaches, but must consider as a part of its system, the various storage yards and adjuncts that go to make the complete unit. It is just as important to provide for the proper disposition of empty cars for cleaning and reloading, as it is to bring into the station solid train loads of people. Due to the breaking up of trains for car transfer and the separation of the baggage, mail and express business, the necessary amount of switching is considerable, and the approaches of the tracks to the trainshed should permit such movement with as little interference with regular trains as possible. As convenience for passengers to reach the main city thoroughfares is desirable, passenger stations are usually built near the heart of a town where property is very valuable, and the economic use of every available portion of the none too large tract usually assigned for station facilities must be made without introducing conditions of extreme grade or curvature which might make reconstruction necessary in the near future. While long tracks under a trainshed are desirable, it is just as important that these same tracks be readily accessible with rapid and parallel movements of trains.

The St. Louis union station instead of being a terminal station such as Boston or New York, or an intermediate station like Pittsburg or Philadelphia, is essentially a transfer point. Located in the center of the Mississippi Valley, St. Louis is entered by railways from all directions, and solid trains of cars are brought in which stop at this point, but each bringing passengers, mail, baggage and express for interchange and distribution among the others. Another fact explaining the necessity for large train space in this station is the very small percentage of suburban business as compared with the through traffic, a condition somewhat unusual in a city of such a size. St. Louis in 1900 had only 975,000 people within a radius of 50 miles (the usual suburban limit); Boston, with about the same population, had 2,400,000 within the same limits, and Chicago had 1,200,000. Of the 278 daily trains (including in and out bound) using the St. Louis union station, not more than 43% are in suburban service, while of the 840 scheduled trains out of the South Boston station about 66% are suburban, and of the 316 trains out of the Illinois Central Ry. station in Chicago 77% are suburban. The trains come into the St. Louis station from the east and the west and instead of heading in directly towards the head house, they run by the station and back in over the Y, thus enabling the passengers in the first-class coaches and Pullman cars to reach the gates first and not be inconvenienced by baggage and mail trucks. Five railways go out from the west end, while the rest of the 22 lines using the station run eastward, being diverted either over the Eads Bridge, the Merchants Bridge farther north, or along the west bank of the Mississippi.

In order to avoid the tunnel, which all trains running over the Eads Bridge are compelled to use in order to reach the station, it was proposed to build an elevated steel viaduct running from the west end of the main spans and curving southward on a down grade to a connection with the present double-track elevated structure now used by all other trains from the east. With the additional two-track elevated line which was also planned from this junction point around to the station (a distance of about 6,600 ft.) it was thought that congestion to the east would be greatly relieved, as but four-minute train service is permissible through the tunnel, where local conditions will not permit the alleviation of the dense smoke. As an absolute block system permitting but one train in the tunnel on each track at a time is permissible, and as 15 miles an hour is good speed through the tunnel, whose grades are 80 ft. per mile, and where construction will not permit perfect track drainage or sufficient curve elevation, the outlet of trains from the station towards the east is somewhat hampered. On the west side, however, two main line tracks have been built upon which to run the western trains and the heavy traffic during the World's Fair. These main tracks are interlocked at all junction points, and block signaled throughout in order to permit service at half-minute intervals.

The present passenger coach storage yards being now taxed to their limits, four of the freight yards in the Mill Creek valley adjacent to the station have been concentrated at Compton Ave. in order to make room for the storage of 350 cars additional, and a new yard has been built at Atlantic St. to hold 250 cars formerly stored at a 21st St. yard just west of the station, but which has been removed to make room for the new express buildings mentioned later. All of these yards are equipped with steam, air and water for the proper heating and cleaning of cars, and are so located with respect to the main track leads into the trainshed, that trains can be switched in and out of the yards very rapidly. Just east of the new express houses is a new express car yard which will enable each of the five express companies to truck from their respective houses directly into cars placed alongside. To the west of these express houses is a team yard, which will allow for teaming to the various mail, baggage, milk, express, and theatrical cars set in here as they are cut off of the regular trains in the shed, thus eliminating much hand trucking formerly necessary at that point.

Hitherto, it has been the custom to handle all trains over the Eads Bridge by a Terminal Co.'s engine, relaying the various road engines at East St. Louis. Now, however, since some of the lines will haul their own trains across that bridge, and to provide proper facilities for all engines using the station, three new engine houses, with a total capacity of 60 engines, have been built. These are rectangular in shape and are served by four electric transfer tables, running in two long pits. In order to coal these engines, as well as all switch engines in the vicinity, a large coaling plant of 1,000 tons capacity has been erected just west of the engine houses, and provides for cleaning ash-pans and supplying coal, sand and water to the engines in the shortest possible time. It accommodates at one time 21 engines cleaning, seven of which can also be coaling.

Last year 1,100 passengers and second-class cars were daily handled through the union station and the enormous amount of switching necessary to properly dispose of them required 1,800 train movements daily, with a total of 2,000 lever movements on the interlocking machine which

*Engineering News, 1891, II., 300; 1892, I., 332, 394, 436.

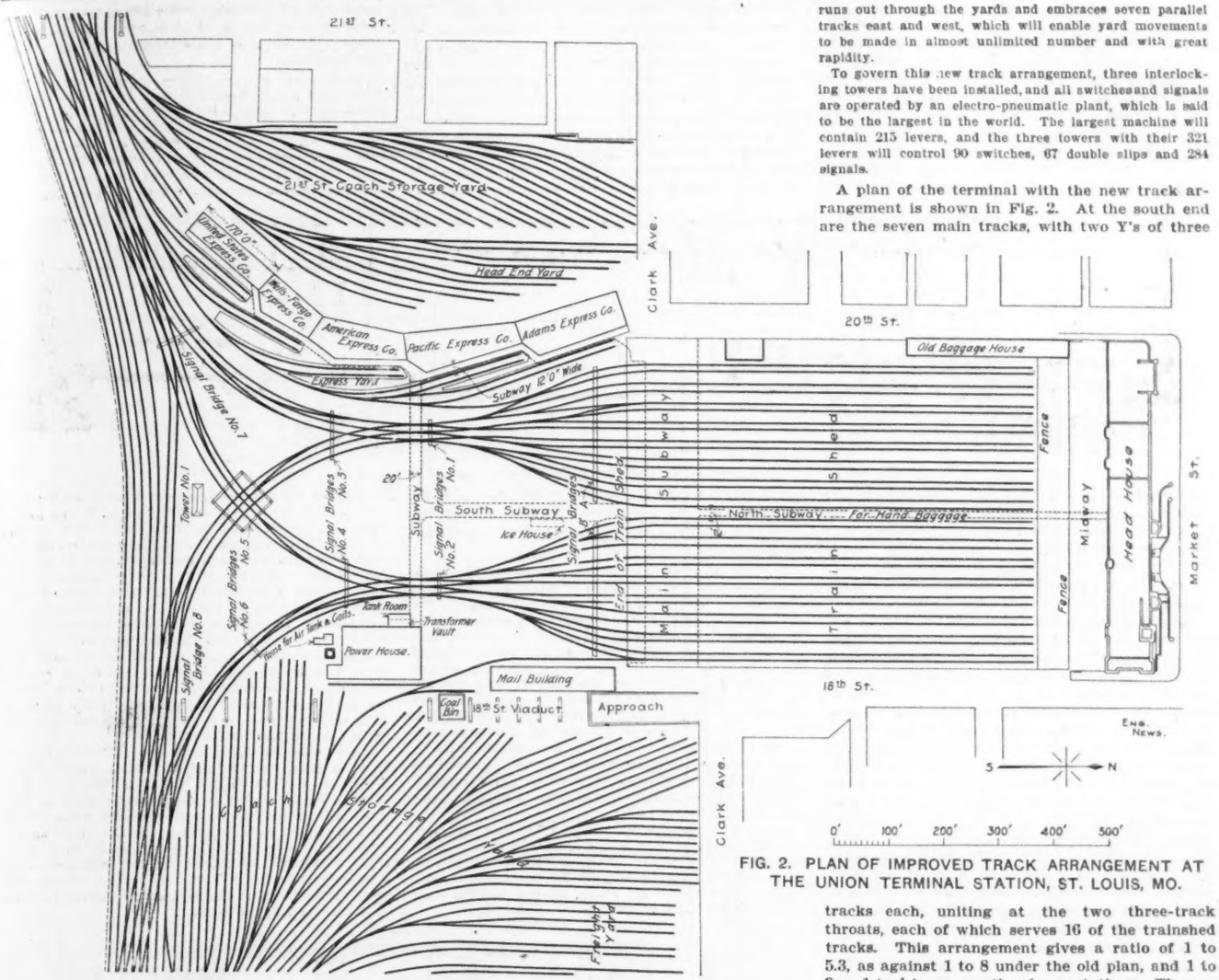


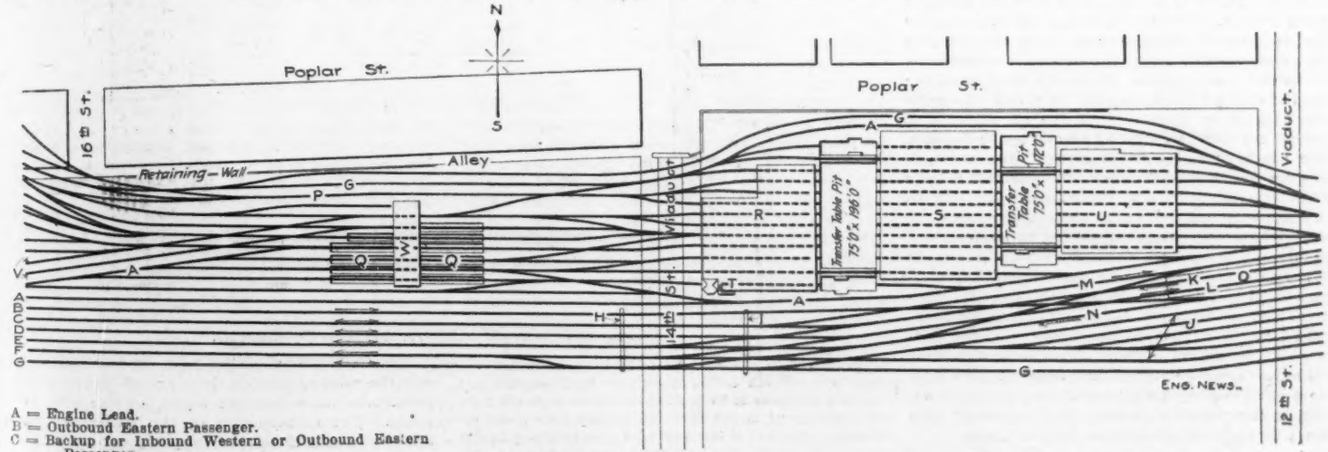
FIG. 2. PLAN OF IMPROVED TRACK ARRANGEMENT AT THE UNION TERMINAL STATION, ST. LOUIS, MO.

governed all switches and signals at the station. The old track arrangement into the station narrowed into a four-track throat through which all movements into and out of the trainshed had to be made. Due to the great number of simultaneous moves necessary to keep traffic running at this station, and the necessary method of handling business, seldom more than three and usually not more than two parallel moves were made through the throat.

In order to increase the switching and operating capacity of the track arrangement as well as to lengthen the tracks under the present trainshed, an entirely new track arrangement has been built. This new arrangement, resembling in shape two large bottles, will permit six simultaneous moves through its two three-track throats, and will give every track under the trainshed a uniform length to hold 11 cars and an engine. The new track scheme also runs out through the yards and embraces seven parallel tracks east and west, which will enable yard movements to be made in almost unlimited number and with great rapidity.

To govern this new track arrangement, three interlocking towers have been installed, and all switches and signals are operated by an electro-pneumatic plant, which is said to be the largest in the world. The largest machine will contain 215 levers, and the three towers with their 321 levers will control 90 switches, 67 double slips and 284 signals.

A plan of the terminal with the new track arrangement is shown in Fig. 2. At the south end are the seven main tracks, with two Y's of three tracks each, uniting at the two three-track throats, each of which serves 16 of the trainshed tracks. This arrangement gives a ratio of 1 to 5.3, as against 1 to 8 under the old plan, and 1 to 2 or 1 to 4 in many other large stations. The approach curves are of 12½° and 13¼°. The main signal tower is between the main tracks and the Y tracks, and just outside is a rectangular signal bridge composed of four girders and four columns, an arrangement which gives a minimum obstruction to the view. The track approaches to the mail building on the east and the express build-



A = Engine Lead.
B = Outbound Eastern Passenger.
C = Backup for Inbound Western or Outbound Eastern Passenger.
D = Backup for Inbound Western.
E = Backup for Inbound Western or Inbound Eastern Passenger.
F = Inbound Eastern Passenger.
G = Freight Main.
H = Signal Bridge C.
I = Signal Bridge D.
J = 12th St. Yard (Freight).
O = Merchant's Elevated Tracks.
K = Inbound.
L = Outbound.
M = Outbound, Eads Bridge.
N = Inbound, Eads Bridge.
P = Landing Track.
Q = Cleaning Pits.
R = Engine House No. 1, 19 Engines.
S = Engine House No. 2, 24 Engines.
U = Engine House No. 3, 18 Engines.
T = Signal Tower, No. 3.
V = Coach Lead.
W = 1,000-Ton Coaling Plant.

FIG. 3. PLAN OF ENGINE FACILITIES AT THE UNION TERMINAL STATION, ST. LOUIS, MO.

The subway and elevator system is as follows: Under the south end of the trainshed is a wide main subway approached by an incline on the west, which also gives access to the 12-ft. subway serving the basements of the express buildings. The main subway, Fig. 4, has a 40-ft. platform for handling baggage, and two 30-ft. roadways. The platform is used as the main baggage room, and here the transfer wagons from hotels, etc., receive and deliver their loads. On the platform are 17 elevators, one to each of the station platforms above, bringing the baggage trucks within easy distance of the cars, as nearly all trains (inbound and outbound) have the baggage cars at this end of the trainshed. The inbound baggage is in the same way loaded into the truck or elevators, lowered to the subway platform, and then run to the baggage room. On the opposite side of the roadway is a series of 16 bays, half the width of each being occupied by an elevator. These are for mail and express matter, the wagons backing up to the bays in front of the elevators. A row of columns separates the two roadways, and a partition of wood and glass, with doors, protects the baggage handled during transfer.

From this main subway a branch subway 12 ft. wide, with a grade of 0.125% to 0.5% extends north under the middle of the trainshed to the headhouse, a distance of 750 ft. This is for trucking baggage direct from the waiting room, if necessary. A 25-ft. subway extends south from the main subway and connects with a 20-ft. transverse subway which runs to the power house on the east and to the express subway on the west. This T-shaped subway south of the main subway is used for trucking to the buildings, and carries the steam and compressed air pipes, electric wires, etc., from the power house. Owing to the limited width between tracks for the north subway, it was found economical to reduce the thickness of the sidewalls very considerably rather than to build two ordinary parallel retaining walls. In order to resist the thrust from tracks and earth at the top, therefore, transverse 10-in. steel I-beams, required as supports for the pipes and set at intervals of 6 ft., were used as braces by embedding their ends in the top of the wall, while angle iron lugs riveted to the bottom flanges bear against the face of the wall at its thicker part, below the bottom of the ties. The thrust at the bottom of the subway is resisted by the concrete floor. The side walls were built in alternate sections 30 or 60 ft. long, the former when working by day only, and the latter when working by day and night. The sections are bonded together at the top by a line of old steel rails and spikes. This construction is shown in Fig. 5.

For checking the baggage, the pneumatic tube system installed will be very extensive. The baggage storehouse will be on the west side of the station, but passengers will usually not have to use this, as the permanent checking room will be in the headhouse, at one side of the waiting room, although a temporary room for the World's Fair period is located in the old baggage house. The passenger will present his claim check and his ticket at the checking counter. If the article is in storage at the baggage room, the attendant at the counter will put the claim check and a transfer baggage check into a carrier and send them to the baggage room. There the baggage man will locate the article by the storage check, detach one half of the baggage check, and return the other half (with any overweight charge) to the checking counter. For baggage sent direct to the station, and which is delivered by wagons at the subway platform already mentioned, there will be a similar carrier service to an attendant at a central office above this platform. He will distribute the carriers into tubes connecting with a desk at each elevator, so that the baggage room will be relieved entirely of all baggage which passes direct from the transfer wagon to the cars. Definite tracks in the trainshed are assigned to certain railways, and baggage for these lines will be assembled in the subway at the elevators serving these tracks. The main carrier system (from temporary checking counter to subway central) will have 30 tubes 3 ins. diameter; 15 of these are for sending and 15 for return. The permanent counter in the headhouse will have six tubes. Two tubes run from the subway central office to each elevator in the baggage part of the main subway. A combined vacuum and pressure pneumatic system is used. The description of the operation of this plant is somewhat lengthy, but the operations will, in fact, be very rapid, and a saving in time as well as in number of men required will be effected, with increased facility and rapidity of work.

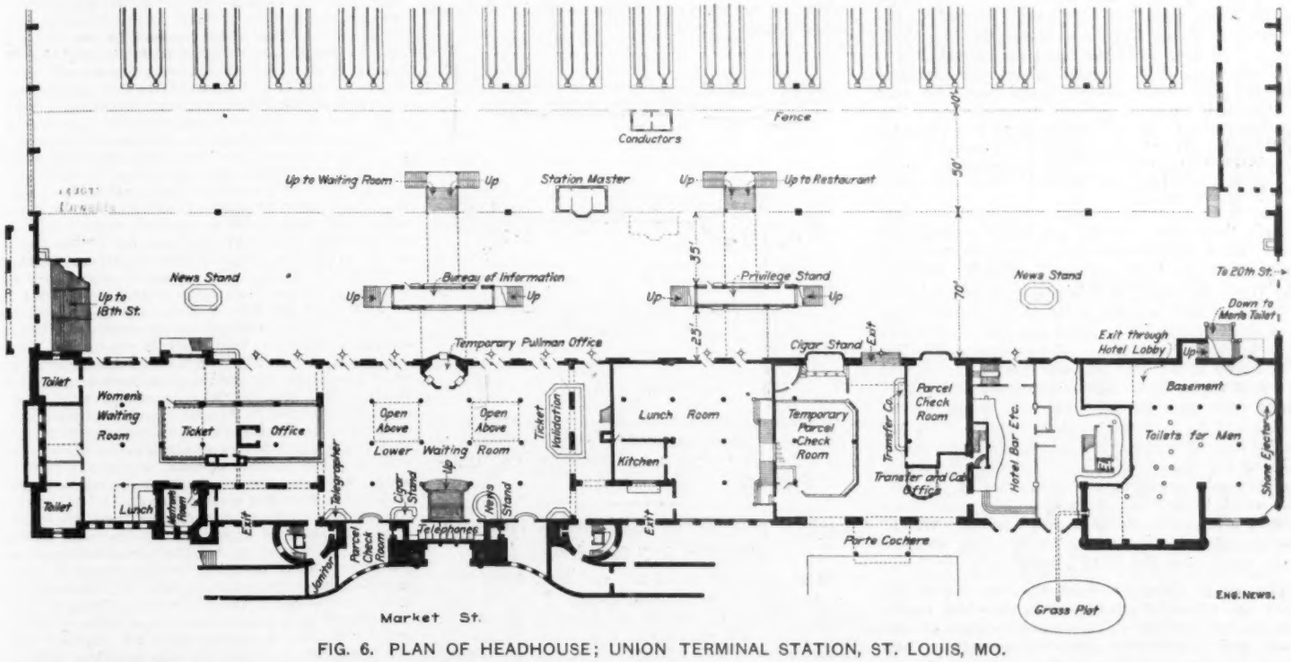


FIG. 6. PLAN OF HEADHOUSE; UNION TERMINAL STATION, ST. LOUIS, MO.

POWER PLANT.

The power house already mentioned is a brick building and contains a complete plant for the following purposes: 1, supply of electric current for signal plants, for the electric lighting of the terminal (including buildings, trainshed, headhouse, subways, yards, etc.) and for the elevators in the headhouse and express buildings; 2, supply of compressed air for cleaning cars and carpets, for testing car brakes, in the yards, and for operating the signal plants and pneumatic tube system; 3, a supply of low-pressure steam for heating the headhouse, and high-pressure steam for the cars and hotel in the station; 4, hydraulic power for elevators in the subways.

For furnishing current for light and power purposes there are four Westinghouse engines of the marine type (cylinders 17 × 24 and 27 × 24 ins.) directly connected to alternating-current revolving-field generators of 350 KW., 1,200 volts. Two rotary converters transform this alternating current to 500-volt direct current for motors and elevators in the headhouse and express buildings. There are also two exciter units, each consisting of a direct-current generator directly connected to a Westinghouse automatic compound engine (11 × 11 and 19 × 11 ins.). Current for the signal and interlocking plant is supplied by a 60-volt direct-current generator directly attached to a Westinghouse engine (cylinders 4 × 4 ins.) and by a bi-polar dynamo bolted to a St. Louis Engine Co.'s vertical engine (cylinder 4 × 5 ins.). Compressed air for the interlocking plant, car service and pneumatic tubes is supplied by two Ingersoll-Sergeant compressors with a capacity of 2,200 cu. ft. of free air per minute, driven by engines of 357 HP. Hydraulic power for the baggage and express elevators in the subway is furnished by three Worthington duplex pumps, with 150 lbs. steam pressure and 800 lbs. hydraulic pressure. The engine room has a Northern Engineering Co's hand power traveling crane of 42 ft. span, 15 tons capacity. Steam is supplied by ten Babcock & Wilcox boilers of 275 HP., fitted with Roney mechanical stokers driven from a Westinghouse 4-HP. "standard" engine. The auxiliary equipment includes two Fairbanks & Morse duplex pumps for washing out boilers, a Nelson duplex pump for the oil supply, and two Cochrane open feed-water heaters and receivers of 1,500 HP. capacity.

HEADHOUSE AND TRAINSHED.

The headhouse and trainshed alterations referred to include the lengthening of the trainshed, which has been increased 180 ft. by adding four new spans at the south end. The effective length of tracks in the trainshed itself, however, has been increased only 120 ft., as the "midway" or platform between the headhouse and the ends of the tracks has been widened 60 ft. The tracks in the trainshed originally had a slight down grade out of the station, but have now been made level throughout their length in order to raise the subway elevations.

With the alterations to other parts of the terminal the headhouse has also come in for a share of attention, partly for general improvement and partly to provide additional facilities for the Exhibition traffic. As originally built, there was a

ings on the west, are entirely independent of the passenger approach, but have a connection with the trainshed tracks so as to give an outlet in either direction. Each of the five express companies has two stub tracks for its own exclusive use, and behind the express buildings are the team tracks. The two principal coach yards are on either side. The passenger tracks are laid with 100-lb. rails of the Am. Soc. C. E. section, having four-bolt Continuous joints; for the yards, 80-lb. rails are used for the leads and re-lay rails for the body tracks. The frogs are of course subjected to very severe service and some anvil-faced frogs with cast-steel fillers are being tried.

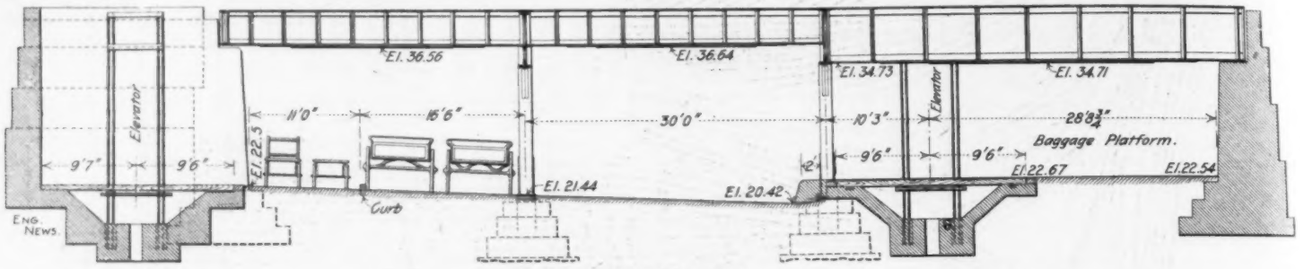


FIG. 4. MAIN SUBWAY.

ENGINE TERMINAL FACILITIES.

Fig. 3 is a plan of the engine facilities made necessary by having to care for the road engines of all passenger trains using the station, as explained in the abstract of Mr. Greensfelder's paper. It must be understood that the passenger tracks in this plan are at right angles to the trainshed tracks in Fig. 2, being directly east, or beyond the Y connections. The coaling station, 36 × 115 ft., spans seven tracks, and on either side are the ash tracks over pits 87 ft. long. This plant was built and installed by the Link Belt Machinery Co., of Chicago. Beyond this are the three rectangular engine houses with two transfer table pits between them, each pit having two electric transfer tables built by Geo. P. Nichols & Bro., of Chicago. This interesting arrangement was noted in the editorial on circular and rectangular engine houses in our issue of March 3, 1904. It was originally intended to have a third transfer table forming the east approach, but by shifting the buildings a little further from the viaduct approach, it was found practicable to connect all the house tracks with the leads by switches. The longitudinal arrangement of tracks admits of setting the roof trusses between the tracks and so keeping the roof low.

The coaling station is a steel structure. Coal cars on two tracks are handled by a cable from an electric hoisting engine, and dump their contents into hoppers feeding short conveyors which deliver the coal to underground crushers between these tracks. There are two crushers, and the coal is delivered to an elevator which raises it to a conveyor running above the overhead storage bin of 1,000 tons capacity. From the bottom of the bin the coal passes by gravity to a row of weighing pockets on each side of the structure, and from these it is delivered by chutes to the tenders. The bin is trough-shaped, giving room on each side for a cylindrical water tank of 20,000 gallons capacity. Each tank is 6½ ft. diameter and 85 ft. long, with connections to the tender spouts. A sand bin is also mounted in the superstructure. At the cleaning pits the ashes are discharged into small cars, and these are run to the center of the pit and discharge into a conveyor and elevator which raises them to an overhead bin. The crushers, conveyors, etc., are operated by induction motors. It is estimated that 400 engines can be served here in a ten-hour day, the plant handling 2,000 tons of coal in that time, with both crushers at work. At the present time about 80 engines per day are handled here.

MAIL, EXPRESS AND BAGGAGE.

By comparing the plans of the old and new arrangements in Figs. 1 and 2, it will be seen that all the express buildings have been transferred from the east to the west side, and it was necessary to have the new buildings ready for use before the old ones could be abandoned. The buildings have brick walls and "slow-burning" interior construction. They are arranged on a curve, but are offset so that each of the five buildings has two stub tracks, as already explained. On the east side, a new mail building has been erected, and also a power house. To avoid the trouble of trucking baggage along the platforms, and the additional trouble involved by the necessity of cutting long trains to allow the trucks to pass across the tracks from platform to platform, a complete system of subways and elevators has been established. This part of the terminal facilities is mentioned in Mr. Greensfelder's paper as follows:

In order to accomplish the new plan for track enlargement, the only growth possible was east and west; this required the removal of the old express buildings on the east side, the destruction of the old power house, and the conversion of the large storage yard on the west side into space for five new express buildings, and the express and head end yards. The new express buildings are built of red brick in one continuous block 838 ft. long, and are two-storied with basement. A new power house has been erected and will generate 2,750 HP. It is equipped with 10 batteries of boilers of 275 HP. each, automatically stoked, mechanically fed with coal and cleared of ashes in the same manner. The engine room contains two large air compressors, four 400-HP. direct-connected alternating-current generators, exciters, pumps for a hydraulic elevator system, heaters, etc.

A new large two-story mail building has been built, and a large baggage building is also to be built if proper city legislation can be secured. The present trainshed, 630 ft long by 601 ft., is being extended 180 ft. south to a total length of 810 ft. over the tracks, and will contain 11.18 acres and 4.55 miles of track.

Because of its character as an interchange station, the quantities of such head-end stuff as mail, baggage and express that have to be handled on trucks from one train to another, and to and from the various houses, are extremely large, and it is a source of considerable difficulty to properly handle this. All this trucking has to be done at the present time over a runway at the south end of the trainshed, crossing on grade each of the 32 tracks. In the morning and evening periods when this business is very heavy, trains are arriving and departing every minute or so, and switching movements are almost continuous, so that rapid movement across the truck runway is impossible and uncertain. These delays, being heightened by the time required to cut all long trains at this runway, made it necessary to originate some plan for relieving this congestion.

An overhead plan of bridges and elevators was suggested, but was abandoned in favor of a subway arrangement. A very comprehensive plan of handling this business has been devised, by means of a system of subways which eliminates all grade crossings of trucks and trains and locates within short hauls and elevator lifts this business requiring rapid and uncrowded movement. The main subway parallels the south end of the trainshed, being covered by the new extension, and crosses under the 32 tracks. It is 600 ft. long and 120 ft. wide, divided by two rows of columns and the south wall into a 40-ft. baggage room on the north side, a 30-ft. roadway adjacent for baggage wagons, another 30-ft. roadway for express and mail wagons and trucks, and 20 ft. more for elevators. Each pair of tracks in the shed is served by two hydraulic elevators, one each for the baggage and express parts of the main subway; these elevators are run at a speed of 150 ft. per minute, carrying 4,000 lbs. on a platform 5 × 19 ft. Wagon entrances are built at each end, and all matter can be brought directly into the subway and transferred immediately to trains standing on the tracks above. There are 32 deck plate girder bridges, with trough floors, to carry the tracks over the subway, and sidewalk glass will admit light between the platforms.

In addition to the main subway, branch subways are run to the baggage, mail and express buildings and the power house, as well as to the Union Station headhouse. Through the latter will be run pneumatic tubes for carrying to the main subway, baggage checks which will be received in the main waiting room, thus enabling far quicker service than if the passenger had to walk to the baggage room for his checks. All the subways will be artificially lighted by electricity and will be equipped with many conveniences for the rapid and economical handling of the various kinds of business.

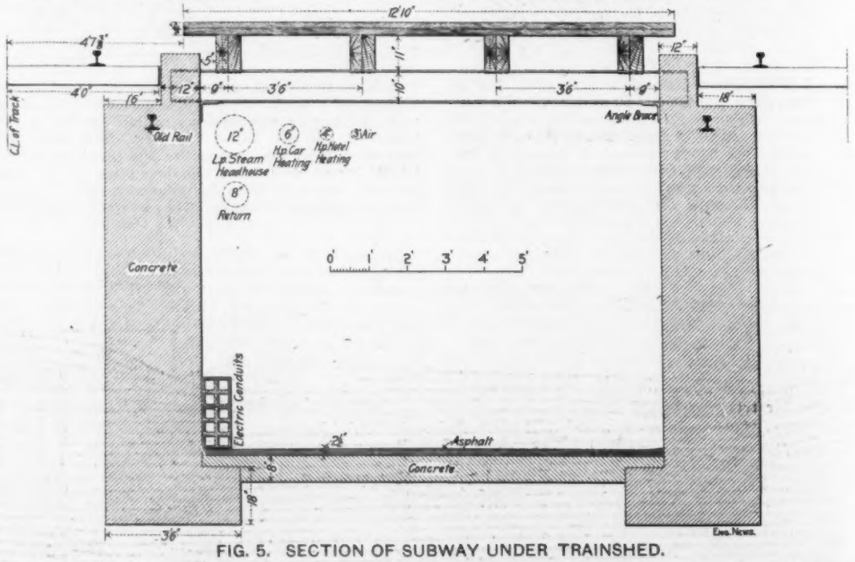


FIG. 5. SECTION OF SUBWAY UNDER TRAINSHED.

The foundations of the new express buildings and the subway serving them are of concrete; the basements have concrete floors covered with asphalt. The construction of the basements and subway necessitated the lowering of one of the main city sewers, and as this is subject to back pressure during times of high water in the river, the new sewer is built of reinforced concrete. Drainage of the basements and subway is provided for by drains leading to a sump containing two Shone ejectors.

large waiting room above the street level and main waiting room below (level with the platforms), the latter being adjacent to the ticket offices, restaurant, etc. It was found, however, that the upper room was practically useless, as passengers naturally gravitated to the main waiting room and its facilities. A large well or opening was therefore cut in the floor of the upper room, thus greatly improving the appearance and the ventilation of the room below. In order to encourage the use of this upper floor, and so to prevent congestion of the crowds, the middle part of this well has been closed, and a door made in the side wall, opening onto a bridge over the "midway," which is reached by steps. A similar arrangement of bridge and steps gives access to the restaurant on the same floor. A plan of the lower floor of the station, as now altered, is shown in Fig. 6.

The ticket office, instead of having two rows of windows is now a rectangular office with windows on all sides. The space within the headhouse originally used for cabs and omnibuses is now fitted up with temporary parcel checking rooms, and the vehicles are transferred to an open space in front, where an ornamental portico or porte-cochere has been built to protect passengers from the rain in going to and from the vehicles. The men's toilet room has also been removed to the basement of the Terminal Hotel (in the headhouse). A feature of the toilet accommodation is the provision of a number of private compartments with closet, wash basin, hot and cold water, soap, towels, mirror, brushes, etc. The charge for the use of a room is 10 cts. Besides the permanent changes, there are numerous special ticket, checking and other facilities for visitors to the Exhibition.

The "midway" was formerly blocked by several booths built either in the middle or against the wall. Most of these are now removed to the space under the two bridges, thus materially clearing the area. In widening this platform, the original iron fence with gateways for ticket examination was moved south 70 ft., but a new inner fence has been built 50 ft. inside it. The general public has free access to the part between the headhouse and the first fence, 70 ft. wide. Gatemen at the first fence only pass persons who are going to the trains, but do not examine their tickets. This excludes the persons who are merely waiting around, relieves the ticket examiners at the second fence, and prevents crowding and confusion of the people, which is very necessary at a time when there is such a heavy traffic of crowded trains. Within the second fence there is a 10-ft. width of platform connecting the train platforms.

The great difficulty with all this work has been the necessity of executing it while traffic was in full swing. The reconstruction of the track and interlocking systems, especially, has taxed the energy and ingenuity of the engineering and operating staff. But with the alterations completed, the handling of passengers and trains is greatly facilitated, and it is expected that the terminal will be able to conveniently handle the enormous Exhibition traffic of the next few months.

A HAND-POWER ROTARY MINING DRILL.

The principal feature of interest in the hand drill shown in Figs. 1 and 2 is the method of mounting or supporting it while in use. Drills are commonly supported upon columns, but this drill is supported upon a steel rod driven into the rock. The rod, a, is wedge-shaped at one end, so that it can be driven into a crevice or into a hole started with a pick, until it is solid enough to support the drill. Upon this rod, a, is mounted an arm, b, which can be rotated about the axle, d, and held in any desired position by the pin, m. This arm supports the drill. Simple and effective as this method of support has proved to be in the Cleveland (England) iron mines, it is a comparatively recent invention. Prior to its introduction, drills were supported upon columns, which were not only heavy, but could not be set up until the muck had been cleared away, resulting in much lost drill time.

It suggests itself to us that this same form of mounting might be adapted to small rotary drills operated by compressed air. Wherever power is used in drilling, the tendency has been to make the drills large and heavy, but there are unquestionably many classes of work where a light machine proves the most economical. This is seen in the increasing use of pneumatic plug drills for block-holing, and in the use of hand-operated

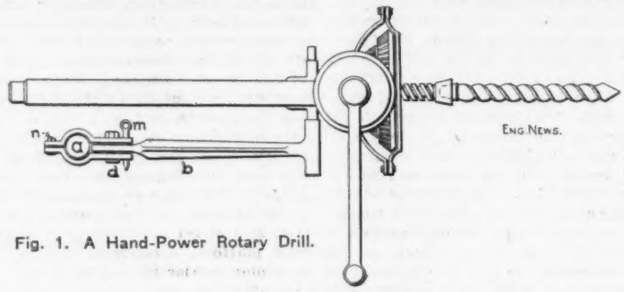


Fig. 1. A Hand-Power Rotary Drill.

rotary drills for drilling shale, coal and soft iron ore, as exemplified in the machine here shown. It is estimated that 47% of the total output of Cleveland ironstone is won by the use of hand rotary drills, 28% by air rotary drills, and 27% by hand churn drills.

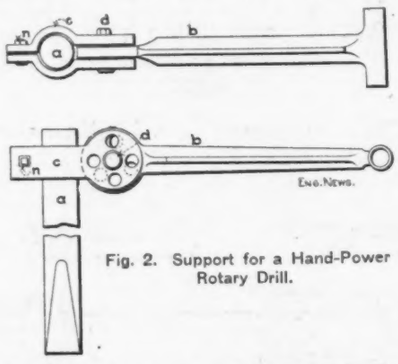


Fig. 2. Support for a Hand-Power Rotary Drill.

Our illustrations are reproduced from "The Iron and Coal Trades Review" of London. The drill is manufactured by Blackett, Hutton & Co., Guisbro, England.

AMERICAN PRACTICE IN HIGH-TENSION LINE CONSTRUCTION AND OPERATION.*

By F. A. C. Perrine,† M. Am. Inst. Elec. E.

A characteristic of American practice is that it tends toward standards not only in the matter of the sizes of units, speeds and manufacture appearance, but also in the methods of producing results and in types of engineering.

The work of the transmission engineer lies in fields so essentially dissimilar that even in spite of this general tendency it may be difficult at first view to ascertain what is the American practice in work of this class. On closer examination one finds, however, this work falling into natural groups dependent on the length of transmission and the voltage employed, though what has been done has been materially modified by the date of erection, since during the past ten years modifications in the arts have been necessarily reflected in the types of construction.

The general groups have been somewhat decided by the manufacturers of machinery, who have presented as preferable certain available voltages. Above 2,400 volts, where transmission proper really begins, the first voltage now commonly employed is 6,600, which figure has been established as standard by the needs of the lighting plants in the great cities, and has been adopted by the transmission companies in place of either a higher or lower voltage mainly because it is a standard. For this voltage direct generation at high pressure is almost invariably used. The next higher voltage now commonly employed, and practically the first one for which step-up transformers are used, is 15,000. During the past few years this has taken the place of transmissions at 10,000, 12,000 and 13,000, and it is to-day the established voltage for high-tension electric railways, the general reason for its establishment as a standard being that this voltage is not more difficult to handle, as regards insulation or switching, than the three last-mentioned lower voltages, and, furthermore, that, where the lower voltages have been previously established, the sphere of operation of the transmission plant has been found to be rather too limited. There are in the Rocky Mountain region and west a great number of the older plants operating at 10,000 volts, and whenever direct high-voltage generation has been attempted, voltages of from 12,000 to 13,000 volts are used; but, at the same time, the majority of the plants which have used the lower pressures in the past, to-day have circuits with special transformers operating at the higher figure.

The next step is to 25,000 volts, which is the highest figure reached without special study of insulators, switches and lighting arresters. This voltage has been successfully handled without serious trouble during the past six years. A voltage of 35,000 is employed in a number of plants built about five years ago, and at this figure the special difficulties due to line capacity, insulator size, erratic lightning-arrester effects and switching begin to make themselves seriously felt. Above 33,000 volts the standard voltage is called 60,000, although in all plants that have heretofore been established to operate at this pressure, there have been installed transformers arranged for connection to various voltages of from 40,000 up to 60,000 volts, and the majority of these plants are to-day operating at about 50,000 volts, some of them being unable to operate at the highest pressure on account of the character of line insulators originally installed. In the choice of voltage for any transmission it is considered the best practice to establish it at the rate of 1,000 volts per mile, provided the length of transmission be not above 60 miles, since above 60,000 volts no commercial work has been regularly attempted.

In the generation of power the revolving-armature machine has almost disappeared from the new plants, and revolving field generators have become so settled in type that those produced by different manufacturers are hardly distinguishable by the casual observer. For the low-head plants using turbine wheels it is necessary to provide for a 50% increase of speed, and in the high-head plants, where impulse wheels are employed, a strength sufficient to withstand a speed increase of 100% must be allowed to provide against damage from overspeeding, should the power be thrown off and the water continue to flow. The machine fulfilling these conditions and practically adopted by all the manufacturers is characteristically a revolving field machine with the poles keyed to a cast-steel spider, the field windings being of copper strip wound upon edge, the armature being constructed of a cast-iron box girder supporting the stationary armature laminations. Almost the only departure from this type of construction for power-transmission work is found in the balanced type of inductor machine, where the field is magnetized by a central stationary field coil wound with copper strip, the armature in two halves symmetrically arranged around the central core being of laminations supported either by cast-iron rings connected together by cold-rolled steel bars or supported by a steel shell to which the armature laminations are keyed.

Various station voltages have been employed, but, where direct generation at 6,000 or 12,000 volts has not been resorted to, the practice is setting more and more to the use of about 2,300 volts, this being chosen because the lower voltages require larger extra station copper and the higher voltages are felt to introduce unnecessary station difficulties of insulation and switching. For switching, the present type of 2,300-volt oil switch has been so well developed, by reason of the great number of plants operating at this pressure, that for handling a particular amount of energy it is both cheaper and better than any 500-volt switch on the market.

For plants operating at less than 25,000 volts, the step-up transformers in use are about equally divided between the water-cooled oil-filled types and air-blast types. Where a good supply of water is to be readily obtained, the oil-filled transformers have generally been given preference, as they can be more readily adjusted for a varying flow of water at different loads. The question of the relative fire risk from the two types has been extensively discussed, and it can hardly be said that any very definite conclusion has been finally reached, though the weight of opinion seems by far to be that the fire brick is at least not increased by the use of the oil-filled transformer, and the actual risk in either type seems to be a matter largely

*Abstract of paper presented at the International Electrical Congress, at St. Louis, Mo., Sept. 12-17.

†Pittsfield, Mass.

of installation. It is perfectly true that there have been some very serious fires, resulting in the complete destruction of power plants, where oil-filled transformers have been used, but in each case the fire has started outside of the transformers, though they themselves, by reason of being installed without reference to safety in case of fire, have furnished fuel which has augmented the conflagration. To-day the conditions of installation for safety are better understood, and it now only remains to be decided whether, in the case of a fire actually arising, the oil shall be run out and the transformer cases filled with water, or the whole transformer protected either by running in an excessive amount of water through their cooling coils or by so installing them that the transformers may temporarily be submerged to within a few inches of their tops. Actual protection of transformers by running water through their cooling coils has been found to be effective in at least one serious fire.

For high-tension switching, use has been made of a long arc-breaker between carbon terminals, and long inclosed fuse (a fuse drawn through a tube filled with a fine, non-conducting powder) and of oil switches. The first two types, while interrupting the circuit well, draw an arc of excessive length and produce a surging which may result in an increased potential of at least as much as 50%. In consequence, these types are rapidly disappearing, except in plants operating at 15,000 volts and below, where the carbon break is preferred to the inclosed fuse, though it is common to install the two in series, allowing the fuse to operate as a safety device, but not for the purpose of switching. The type of fuse where wire is drawn through a tube filled with powder was found to operate successfully up to 40,000 volts and without serious surging on the circuit, but the powder being blown out with great force, scattered over the entire station, and is in consequence not allowable. The oil switches mainly employed are those with the vertical break and those with the horizontal break. The vertical-break switch has the advantage that the amount of oil contained in the oil-tank is relatively small, and will add to possible conflagration only a slight amount of fuel. This switch is often found on severe short-circuits blowing all the oil out of the tank unless the tank is built very strongly, when it becomes necessary to insulate the plunger from the tank as it enters the switch. The horizontal-break switch, while containing a large amount of oil, will for the same length of break handle about 25% more energy at any definite potential. This switch can successfully be used at 60,000 volts, and up to the present time has not been found to blow the oil from the tank. The two types of oil-switch are the standard to-day, no distinct preference being given to the horizontal switch, though the writer believes that in the future this type will be used as a standard for the highest potentials.

Transmission with two-phase connection of circuits, whether using three or four wires, has for voltages above 6,600 given place entirely to transmission with a three-phase connection, though three-phase transmission with two-phase distribution described by Mr. Scott at the International Congress of 1893 is very extensively employed.

The relative merits of the delta and star connection of the lines to the transformers is still somewhat in dispute, so much so that in plants of the highest voltage, where several voltages are provided, certain of the lower voltages are obtained by delta connections to the transformers, while the higher voltages are to be obtained by a star connection. In general it may be stated that up to 25,000 volts the delta connection is generally preferred, principally because with this connection a ground upon one line does not necessarily result in a short-circuit, and, furthermore, the service is not necessarily interrupted in the case of the failure of a single transformer. At voltages higher than 25,000 volts the transformers for delta connection become more difficult to build and insulate. Furthermore, a single ground anywhere produces disturbances of a serious character, and in consequence the star connection with the grounded neutral is employed, advantage being taken of the fact that a grounded neutral aids in the distribution of unbalanced loads, and furthermore the rise of pressure which may occur from line discharge at the time of an open-circuit or a short circuit are not so likely to produce serious results.

For the distribution of current through the low-tension mains, it is generally the custom to transform to 2,300 volts two-phase unless either the load is mainly one of motors, or there are important motors of considerable size to be supplied at a distance of half a mile or more from the sub-station. In such cases three-phase star-connected four-wire distribution is employed, allowing the connection of distributing devices either to a 2,300-volt circuit between lines and the neutral wire, or a connection to a 4,000-volt delta circuit for balanced loads. This combination of circuits is found to be extremely useful where a mixed load is to be supplied at varying distances.

The high-tension lines are preferably run over private right of way. Railway rights of way were at first highly prized on account of the entire absence of trees and disturbing structures, and furthermore on account of the fact that inspection and repairs are most easily provided for; but experience with such lines has proven that, for transmissions at even so low a tension as 15,000 volts, the interference with insulation by the smoke from the locomotives, which covers the insulators, more than counterbalances all the advantages, and to-day such rights of way are more commonly shunned than sought. Where locomotive smoke combined with sea fog is encountered, it becomes absolutely necessary to clean each insulator at frequent periods, even though the voltage of transmission be not more than 5,000 or 10,000. Along the country road this difficulty is not apparent, but in some localities farm structures and trees interfere with the transmission, so that in general it may be said that a private right of way that the transmission company can absolutely control is much to be preferred.

In the most recent types of construction the height of pole is limited as much as possible. While there may be some increased security from malicious disturbance in the use of high poles and decrease of line capacity may be expected, these advantages are only obtained at the expense of stability and at an increased cost. A pole 35 ft. high set 5 ft. in the ground permits the safe installation of either a single three-phase line with a spread of as much as 6 ft. by supporting one insulator on the top of the pole and the other two on the ends of a long cross-arm; or it may be used to support two three-phase circuits on opposite sides of the pole with a spread between wires of 3 ft. by the use of two cross-arms, and at the same time such a pole permits the safe installation of telephone or other signaling circuits on brackets or cross-arms at a safe distance below the power lines. These poles should not be less than 8 ins. diameter at the top and 12 ins. at the ground line. Variations from these dimensions may be considered as being due to special considerations based upon the location of the lines or arrangement of the circuits. It is true that such a standard pole may only be arrived at after a consideration of the wind stresses on the particular lines taken in conjunction with the spacing of the poles, but the maximum pole spacing on transmission lines is about 135 ft., and at average wind velocities the pole dimensions may be considered safe. Extra strength required by variations of wind stress, either due to an increase in the number of wires or to a necessity for allowance for sleet, is more commonly taken care of by shortening the spans than by an increase in the size of the pole. In some cases where severe sleet conditions are to be encountered and the wires changed, it is the practice to install these poles not more than 50 ft. apart.

The material used for poles depends largely on the locality. In the southeastern states chestnut is the favorite wood; along the Canadian border and through the Rocky Mountain regions cedar is employed, while square-sawn redwood is used almost exclusively on the Pacific coast. With increase in voltages and consequent increased trouble from insulators, a demand has arisen for a pole-line construction which will permit a decrease in the number of insulators and allow an increase in the size of each. This has been accomplished by the use of galvanized-iron towers not less than 40 ft. from the ground-line to the wires, and spaced about 500 ft. apart. One plant in Mexico has recently successfully installed this method of construction. A second in the same country has contracted for its material, and a number of plants in the United States are contemplating its use. The question of the life of wooden poles depends not only upon the character of the wood and its condition when cut, but also upon the local conditions of atmosphere and soil. In some places the poles which are available have no longer life than about five years, and, in the extreme, wooden poles cannot be greatly depended upon for a period greater than 15 years, though the redwood poles installed along the lines of the transcontinental railroads west of the Rocky Mountains have in many instances given a life up to 35 years, and are still found to be in good condition; but these poles are set into a soil strongly impregnated with alkali in a country where rains are few and the air generally dry. Nothing is known as yet of the life of the galvanized-iron towers except from windmill practice, where towers which have been galvanized after all punching and machining is done are found to be in good condition after a period of 10 to 15 years.

The cross-arms in use are almost invariably made of pine without treatment other than painting. These arms are let into the pole from 1 to 2 ins. being held by bolts through the pole and arm, and when long are additionally supported by braces. Even with higher poles wood arms are used, the general feeling being that there is less probability of the circuit being completely disabled should an insulator break and the line fall, if it falls upon a wooden rather than a steel arm. At the same time an experiment in the use of wooden braces has not been found to result in any advantage. In consequence flat galvanized-iron braces established a number of years ago, as standard by the telegraph and telephone companies are now almost universally employed in the construction of transmission lines. With increase in spans and voltages the insulators are increasing in size. This condition will probably in the future demand a strength of arm greater than can be obtained by the use of wood. This problem, however, has not as yet obtained a definite solution.

For plants operating below 25,000 volts much use has been made of glass as a material for insulators. Glass has been for many years the standard insulator material in American telegraph and telephone practice, and in spite of many experiments that have been tried with porcelain, it is still considered the best and cheapest material for this service. However, in transmission work one of the great advantages claimed for glass in telephone and telegraph practice disappears. The engineers of these companies claim that it is important to provide against dark, narrow spaces within the insulators on account of the fact that they form the homes of insects. The transparency of the glass largely obviates this difficulty. Where large insulators are used such as are employed by transmission companies, the spaces within the insulators are well lighted from below, and the transparency of the material is not important. Glass is comparatively fragile, and for transmission work it has nothing to recommend it except low first cost and cheap inspection; these, to be sure, are very often overpowering advantages when the voltage is low enough, so that the particular form of insulator used gives a large factor of safety, and in consequence up to 15,000 volts glass insulators are generally preferred unless there are special climatic conditions which render them liable to fracture.

Many series of tests have shown conclusively that the porcelain insulator has a greater mechanical strength, is less liable to surface leakage, has a safe dielectric strength, and in addition that it is exceedingly difficult to so break the head of a porcelain insulator as to allow the wire to fall away from it. The one disadvantage of porcelain is that there is an uncertainty as to its solidity, and that it is only possible to ascertain its solidity by most careful high-voltage tests. The question of the form of high-voltage insulator as yet is in dispute. Operating engineers seem to be inclined to a design where the petticoats are very long and comparatively close together, so that great creeping distance be given over the surface of the insulator between line and line and between line and pin, comparatively little regard being placed on the flashing distance. Engineers of the manufacturing companies, however, incline toward one of a much more open type of large diameter and with few petticoats. This latter form undoubtedly gives the greatest sparking distance, has the least dark spaces within it, and is more readily cleaned by rain storms. It is also important that such an insulator be constructed to operate at high voltage without noise, and, as there is a definite loss of energy whenever the insulators on a line are noisy, it may be safely predicted that the open type of insulator is the one that will be in the future considered as the standard.

While insulator size may be largely determined by form, at the same time we may in general note that up to 10,000 volts insulators, whether of glass or porcelain, have a minimum diameter of about 5 ins. A 7-in. insulator can successfully be used on voltages as high as 25,000, a 13-in. insulator is sufficient up to 40,000 volts, while at 60,000 volts it does not seem safe to install insulators having less diameter at the top than 14 ins. A greater size would unquestionably invariably be used for these high voltages if the problems of the manufacture of porcelain and support of the insulator were altogether solved.

For support of insulators on cross-arms it is necessary to provide that the lowest petticoat be raised above the cross-arm as much as the radius of the insulator, and, as the strain comes on the extreme top of the pin, it is obviously difficult to successfully support the largest size of insulators by means of the common pin in cross-arm construction. By using carefully selected woods, this has been successfully accomplished for insulators up to 11 ins. in diameter, but at 40,000 volts in bad weather such insulators carry enough current over the surface to char a wooden pin. Accordingly practice has settled to the use of iron pins in plants operating above 25,000 volts. The wooden pin can be successfully used at this voltage and below, and indeed forms a certain protection to the line by reason of the fact that the pin itself is a safe insulator, and is only in danger of being burned where the insulator is punctured. Above this voltage, howere, only metal pins can be employed, not only on account of the large size of the insulator, but also on account of the fact that there is much burning of wooden pins. The manner in which these pins are burned has attracted considerable attention, having presented some problems which are exceedingly interesting. There is no doubt but that the effect is due to leakage over the surface of the insulator, but it is extremely interesting to note that in some cases the pin is actually charred, whereas in other cases there is an apparent dissociation of something in the wood, and peculiar salts are left behind either reduced from the atmosphere or from the material of the wood itself.

The materials that may be used for pins are locust and eucalyptus. The latter wood is decidedly preferred in the plants west of the Rocky Mountain region and where it is readily available, as the wood has been found to be as strong as hickory, dense, and readily handled when thoroughly seasoned and dried. For the largest sized pins, however, as has already been said, no wood is entirely satisfactory, and in consequence use is made of malleable cast-iron or cast-steel.

As regards conducting material, it may, of course, be said that the only materials at present available are copper and aluminum. For a number of years there has been a discussion of the possible use of iron for short lines on high-potential plants, since the smallest copper wire that may successfully be strung is unnecessarily large under such circumstances. This procedure, however, has not obtained the approval of any of our electrical engineers. The copper wire is invariably uninsulated in high-tension

work, since it is correctly believed that no insulation is a true protection, and the frank nakedness of the bare wire is a warning, and in consequence a safeguard to those who are compelled to work near the line.

Copper is used either soft, hard-drawn or stranded. For transmission work, where the wires are smaller than 0.3 in. diameter, use is not made of soft-drawn wire, and it may be stated that the standard in American practice is to use soft-drawn wire only for large, low-potential circuits where the small change in conductivity due to the hard drawing is an important factor. Up to 0.3 in., hard-drawn copper may be considered standard. Between 0.3 and 0.4-in. diameter the practice is evenly divided between solid hard-drawn wire and strand. Larger than 0.4-in. strand is almost invariably employed. Some use has been made of solid aluminum, but, as the material must be handled with great care, it has been found generally to be the better practice to employ aluminum strand, which is more readily installed and more reliable after installation.

Preference between aluminum and copper is almost entirely a matter of price for transmission lines. It is true that aluminum is stronger in reference to its weight for different conductivities than copper, but at the same time it is materially larger, and the resultant transverse wind stress on the line greater. For short lines, delivering a small amount of power at voltages of 40,000 or above, aluminum is decidedly to be preferred, since it is found that at these voltages a wire less than ¼-in. diameter will discharge through the air, and this discharge may result in a considerable loss of energy. Accordingly, it is not possible at these voltages to successfully use wires less than 0.3-in. diameter, no matter what the amount of energy or the distance. Accordingly where the amount of energy and the distance may result in the loss not being the determining factor, aluminum is much preferable for the reason that at a definite size it is materially cheaper than copper.

Where salt-sea fog is to be encountered, both aluminum and copper are acted upon. The action on aluminum is greater than the action on copper, and in consequence copper must necessarily be used. Where such conditions are not encountered, aluminum is an entirely safe material provided it is not exposed to the elements in contact with any other metal. The joints, therefore, must either be made of aluminum of the same quality as the wire, or the joints must be carefully insulated so that no moisture will penetrate. Aluminum must be strung with careful reference to the temperature at the time of erection, since its coefficient of expansion is very large, about three times the coefficient for copper, and experience in the erection of copper lines will result in an unsafe aluminum line. Careful tables have been prepared as to temperature, span and sag, and, when these tables are followed, no apprehension need be felt as to the safety of the line.

The most difficult problem at present encountered in the construction of high-tension transmission lines is that presented by the lightning arresters. For voltages up to 25,000, the non-arcing types of lightning arresters, either with or without series resistances, may be successfully used. Above this voltage and where large amounts of energy are available, these arresters are found to be short-lived, and up to the present time no thoroughly satisfactory arrester has been presented, which does not, when interrupting the ground circuit after a discharge, injure the insulation of the line and transformers. The horn form of lightning arrester developed in Germany has been found to operate with invariable success so far as the lightning arrester itself is concerned, but, as it is interrupting the ground circuit it draws a large arc, and oscillations are produced on the line, which in many cases have been found to have more serious results than the discharge they were installed to remove. Condensers in parallel with the lightning arresters and ingenious arrangements of arresters and resistances have been used with some success, but none of these plans may be considered to be entirely satisfactory for the highest potentials operated from the largest generating plants.

In the operation of such lines every effort is made toward maintaining continuity of service. Such lines are carefully patrolled, even when it becomes necessary to build a special runway for the patrolman, and it is remarkable with what certainty these experienced men can predict the hours of life of a failing insulator, and provide for voluntary interruption of the service in time to remove the imperfection. Duplicate lines for long-distance work are an invariable necessity, though by far the best protection that can be offered for service is the supply of current from different power stations over lines following different routes. The present tendency is toward the consolidation of plants, not only for the purpose of decreasing the general operating expense, but more particularly providing continuity in the case of the most serious accidents. No difficulty is experienced in operating in parallel plants widely separated, and where a number of plants are feeding into the same network, two certain plants are assigned the regulation of the entire system, others feeding the circuit being allowed to operate their machinery at full load continuously. The line capacity offers the most serious problem in determining regulation where the loads vary widely, but this quality becomes important only for great variations of load, which as the plants increase in size and load are disappearing. Where proper care has been given to the installations of the lines and where duplicate lines and plants are provided for, care in operation and patrol of the lines has resulted in success both from the engineering and financial standpoint.

THE CHICAGO RIVER TUNNELS and the methods for lowering them as required for deepening the river have been reported upon by Mr. George W. Jackson, the engineer appointed to investigate the matter for the council committee on local transportation. Mr. Jackson proposes a subway system in connection with new tunnels, as this will cost but little more than lowering the old tunnels and bringing the approaches to the surface, for the reason that the open cut approaches would involve heavy land damages. The subway system would provide for the territory bounded by Michigan and Chicago Aves., 12th and Halsted Sts. The cost is estimated as follows:

For Lowering Tunnels:	
New north side tunnel	$1,170,000
New west side tunnel	1,030,000
Total	$2,200,000
For Tunnels and Subways (First Plan).	
One north side subway	$1,595,700
One west side subway	2,405,096
Total	$4,000,796
For Tunnels and Subway (Second Plan).	
Two north side systems	$3,455,184
One west side system	2,405,096
Total	$5,860,280

THE LARGEST CONCRETE PILE CONTRACT ever awarded has been let to the Cranford Paving Co., of Washington, D. C. The contract calls for the driving of 4,600 Simplex concrete piles for the foundations of the large warehouses of the Pittsburg Terminal, Warehouse and Transfer Co., of Pittsburg, Pa. The work was started Aug. 17 and 75 days are allowed for its completion. In testing the bearing power of the piles a cluster of four was driven to a depth of 40 ft. and loaded with 175 tons, or nearly 44 tons per pile. Mr. Charles Bickel, of Pittsburg, is the architect in charge of this work, and Mr. George W. Lange is Superintendent for the Cranford Paving Co. It should be added that the contract was awarded as a result of a speed contest with other concrete pile firms.

THE PANAMA CANAL will not be the scene of active construction work until 1906, as Mr. John F. Wallace, M. Am. Soc. C. E., Chief Engineer, states that the work of thoroughly surveying the canal route with a view of determining at what level the canal is to be cut and the exact line it is to follow will consume the remainder of the year 1904 and all of 1905. By the spring of 1906 he expects to have the campaign entirely mapped out and the actual work of digging in systematic progress. Then it will take eight years to complete the work.

The line already marked out by the French company will be followed pretty closely, except that wherever possible curves will be straightened. The cost of completing the canal is $150,000,000; to this must be added $40,000,000 paid to the French canal company and $10,000,000 paid to the Panama government for the grant of land, making a total of $200,000,000. There are now 1,500 men in the field, 500 of whom are in the sanitary department. There are six engineer corps at work, each in charge of a resident engineer.

A DISASTROUS RAILWAY WRECK on the Southern Ry., near Hodges, Tenn., on Sept. 24, cost more than 60 lives. Two passenger trains collided head-on, apparently because the crew of the westbound train forgot or disobeyed its orders to meet the eastbound train at the station back of the point of collision.

SEVERAL PECULIAR RAILWAY ACCIDENTS were recorded in the past few weeks, in addition to the more serious accidents which have been noted in our columns. On Aug. 8 a freight train on the Louisville, Henderson & St. Louis Ry., when near Spottsville, Ky., failed to see that the draw over Green River was open, and ran into the river, killing three of the crew. On Sept. 9 a passenger train on the Seaboard Air Line broke through a trestle some twenty miles south of Monroe, N. C. A few minutes later, a freight train following close behind the passenger train, also went down into the wreckage. The double accident resulted in four deaths, one of them in the freight train. A freight train on the Pennsylvania R. R. got out of control, a few weeks ago, on the mountain section near Altoona, Pa., and going down grade at increasing speed, jumped the track at Kittanning Point curve; two men of the train crew were killed. A westbound passenger train on the New York Central & Hudson River R. R. was in part derailed on Sept. 25, near Lyons, N. Y. The three Pullman cars at the rear of the train were derailed and thrown over on the adjoining track. Some minutes later a fast freight train on this track ran into the wrecked cars, and in this collision one of the passengers was fatally injured.

AN EXPLOSION OF DYNAMITE KILLED ten people and seriously injured at least 15 more in Melrose, Mass., Sept. 21. A 50-lb. box of dynamite had fallen from a delivery wagon upon a street car track, and the explosion occurred when the wheels of a trolley car struck the dynamite. The car was completely wrecked and every window pane within a radius of a quarter of a mile was broken. The driver of the delivery wagon had discovered the loss of the box of dynamite and was returning for it, but before he got within a hundred yards of the box the car came along and was blown up. Three women and a child were among the dead. All on board the car excepting the conductor were either killed outright or maimed.

A WAGON LOAD OF DYNAMITE was struck by a freight train, Sept. 23, on the line of the Baltimore & Ohio R. R. in the village of North Branch, Md. Five cases of dynamite (750 lbs.) were exploded, wrecking the train, killing the engineer and a brakeman, and severely injuring nine other men. Several buildings nearby were destroyed, and every window within half a mile was shattered. The dynamite was being hauled for Mr. M. Elmore, a contractor, and his driver becoming panic stricken when he saw the train coming, abandoned the wagon on the track. It is said that the wagon was carried 50 ft. along the track before the explosion occurred, indicating that the detonation did not occur until some of the dynamite was ground up under the locomotive wheels. Another wagon load of dynamite, following 200 yards in the rear of the first wagon, was not injured.

AN INVESTIGATION OF THE SLOCUM DISASTER has been made by the local Board of Steamboat Inspectors at New York City. The excursion steamship "General Slocum" burned in the East River at New York City on June 15, 1904, and about 900 persons lost their lives—the exact number will never be known. The city authorities' investigations showed that the fire equipment and life belts of the vessel were inadequate and quite non-effective, and that the crew of the vessel did nothing to put out the fire, prevent a panic, or aid the passengers in saving themselves. The vessel had been inspected and passed, little more than a month before the disaster, by an officer of the local Board of Steamboat Inspectors. The investigation just completed by this board throws the entire blame for the great loss of life on the crew of the vessel, and revokes the licenses of the captain of the vessel, the pilot and the chief engineer. The verdict of the Board also exonerates the life belts.

THE NEW SLOW SAND WATER FILTERS AT PHILadelphia appear to be doing very good work. All the water is taken from the Schuylkill River. That for the Upper and Lower Roxborough filters is supplied from the Shawmont pumping station, just above the Flat Rock Dam, and that for the Belmont filters is supplied by the Spring Garden pumps, from below the dam and nearly opposite the Belmont station. The water going to the Upper Roxborough filters has twelve days sedimentation, and that going to the Belmont station has a little more than two days' sedimentation. At Lower Roxborough the water also has between two and three days' sedimentation, in addition to which it is pre-filtered before it goes to the slow sand filter beds. A general description of the new water purification plants completed and under construction at Philadelphia was published in our issue of Aug. 18, 1904. The following figures showing the reductions in bacteria and turbidity at the three filter plants for the week ending Sept. 17, 1904, have been taken from a detailed statement of daily analyses sent to us by Mr. John W. Hill, M. Am. Soc. C. E., Chief Engineer of the Bureau of Filtration. The bacteria in the raw water at Shawmont, the ultimate supply to the Upper and Lower Roxborough filters, averaged 53,000, against 1,200 after sedimentation, and 32 after filtration. The corresponding turbidities were 190, 27 and 0.5. The reductions in the filtered as compared with the settled water were 97.3% for the bacteria and 98% for the turbidity. At Lower Roxborough, sedimentation reduced the bacteria from 53,000 to 12,000, pre-filtration gave a further reduction to 4,000 (66.7%) and ordinary filtration to 31, or 99.22% of the number in the pre-filtered water. The turbidity reductions here were from 190 to 45, to 22 (51% for the pre-filters) and finally to 1, or 95% on the pre-filtered water. The rate of slow sand filtration in some of these filters was as high as 6,000,000 gallons an acre, but none of the five filter beds effected less than 98.7% bacterial reduction, starting with the low bacterial content of 22 per cu. cm. for the pre-filtered water. The water pumped to the Belmont reservoir contained an average of 39,000 bacteria and had a turbidity of 190. After sedimentation, the bacteria numbered 9,000 and the turbidity 44; after filtration the corresponding numbers were 50 and 1, showing a reduction of 99.44% in bacteria and 98% in turbidity for the filtered as compared with the raw water. Of the 18 filters here (one not reported on at all and two for a part of the week only), only one showed more than 100 bacteria per cu. m. (actually 110) in the filtered water, and the percentage reduction in this filter for the week was 98.8. The turbidities reported are based on the silica standard.